The Canadian Entomologist

Vol. LXXXV Ottawa, Canada, March 1953 No. 3

The Morphology of the Chordotonal Organs of the Antenna, Mouthparts and Legs of the Lesser Migratory Grasshopper, *Melanoplus mexicanus mexicanus* (Saussure)[1]

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The chordotonal organs of insects and especially those of the Acrididae are well known. Slifer (1936) lists 76 scoloparia which are distributed throughout the body of *Melanoplus differentialis*. Although the sense organs of *Melanoplus mexicanus* described in this study are, in general, similar to those found by Slifer, her summary account would seem to warrant a more detailed consideration of their structure.

The organ of Johnston in the second segment of the antenna is included because of its structural similarity to the chordotonal organs, although it is usually considered to have a special sensory function distinct from that of the chordotonal type.

Materials and Method

Newly molted adults of *Melanoplus mexicanus mexicanus* (Saussure) (Orthoptera; Acrididae; Cyrtacanthacrinae) and those with fully hardened cuticula were fixed with equal success in solutions of Carnoy-Lebrun (equal parts of 95% alcohol, chloroform and glacial acetic acid; mercuric chloride is added to saturation) or of Susa (50 ml. distilled water with mercuric chloride to saturation: 2 g. trichloroacetic acid: 20 ml. formol: 4 ml. glacial acetic acid: 30 ml. distilled water). The mercuric chloride crystals were removed by iodine in 70% alcohol during hydration of the sections.

Both Parlax (m.p. 52°C.), a rubber-paraffin mixture, and hard paraffin (m.p. 54-56°C.) were used for embedding. Best results were obtained with Parlax: the crystals are smaller, which reduces the danger of trapping air in the block, and its rubbery consistency seems to make for better sectioning.

The sections were stained with Heidenhain's iron-hematoxylin and mounted in balsam or Piccolyte.

All drawings were made with the use of the camera lucida.

CHORDOTONAL ORGANS OF THE ANTENNA

Anatomy of the Antenna

The antenna of *Melanoplus mexicanus* comprises 24 segments. The basal segment or scape is the largest and is slightly flattened dorso-ventrally. The second segment or pedicel is cylindrical, and smaller than the scape, but larger than any of the remaining segments which are all of equal size.

The only articulations in the antenna which will allow for much movement between the adjacent segments are those of the head and scape and of the scape and pedicel. Movement of the antenna as a whole is accomplished by muscles in the head which attach to the tentorium and insert on the base of the scape; the pedicel and flagellum together are moved by muscles in the scape. Musculature is absent from the pedicel and from all segments of the flagellum.

The scape has three muscles: the meso-ventral and latero-ventral muscles, which run distally from the ventral wall of the base of the scape to insert on apodemes arising from the articular membrane of the scape and pedicel, and a smaller mesial muscle which is attached basally to the mesial wall of the scape

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distad of the other muscles, and which joins the meso-ventral muscle distally to insert with it.

The scapal chordotonal organ consists of two large scoloparia (Text Fig. 1 so) attached side by side to the dorsal surface of the scape about one-third of the distance up the segment. From this point distally they diverge, to insert on the base of the pedicel near the attachment of the scapal muscles; the mesial scoloparium inserts with the mesial muscles and the lateral scoloparium with the latero-ventral muscle.

The pedicel contains the organ of Johnston and the pedicel chordotonal organ.

Johnston's organ consists of twelve scoloparia distributed around the periphery of the distal half of the pedicel (Text Fig. 1 oJ). Proximally the scoloparia are in connection with branches of the antennal nerve. Distally they insert in canals in the articular membrane of the pedicel and third segment.

The pedicel chordotonal organ (Text Fig. 1 po) is situated in the distal two-thirds of the segment and inserts in the same manner as a scoloparium of Johnston's organ.

The chordotonal organ of the last segment of the antenna, or tip chordotonal organ, is situated in the distal third of the last segment. It is associated basally with a sensory ganglion and inserts at the cuticula of the tip of the antenna.

The terminology of the nerves follows that of Debauche (1935; 1936; 1938).

The antennal nerve leaves the ventral surface of the deutocerebrum, and, just before entering the antenna, gives off a fine nerve α_1, (Text Fig. 1) which

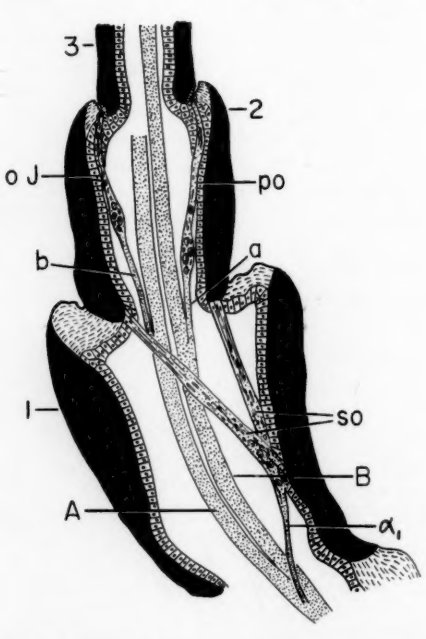


Fig. 1. Schematic vertical longitudinal section of the antenna, α_1, nerve to the scapal chordotonal organ; A,B, principal nerves of the antenna; a,b, branches of the nerves B and A respectively, innervating Johnston's organ and the pedicel chordotonal organ; oJ, Johnston's organ; po, pedicel chordotonal organ; so, scapal chordotonal organ; 1,2,3, segments of the antenna, numbered from the base.

divides immediately before innervating the scoloparia of the scapal chordotonal organ.

At the base of the scape the antennal nerve divides into two large branches, A and B (Text Fig. 1).

In the distal part of the scape A and B each gives off a small branch, *b* and *a* respectively (Text Fig. 1): *a* moves to the mesial side of the pedicel to innervate the pedicel chordotonal organ and five scoloparia of Johnston's organ; *b* moves to the lateral side to innervate the other seven scoloparia of Johnston's organ.

The Scapal Chordotonal Organ

As noted previously, the scapal chordotonal organ consists of two scoloparia with adjacent ganglia attached to the median dorsal surface about one-third of the distance up the scape. The scoloparia are in connection with the nerve α_1, at their proximal ends and are attached to the cuticula by means of supporting fibers (Fig. 1 fs). Distally the scoloparia are attached on opposite sides to the cuticula at the base of the pedicel (Fig. 1).

The mesial scoloparium is the larger, containing about ten scolopidia; the lateral scoloparium contains about five. The scolopalia are distributed along the length of the scoloparium (Fig. 1 sc).

Microscopic Anatomy

The scolopale.—The scolopale is similar to that described by Debauche (1938) for the scapal chordotonal organ of *Schistocerca gregaria* Forsk. It is mononematic, distal connection of the scolopale with the cuticula being made by the cap cell. The scolopale has two axial fibers of the isodynal type (Fig. 1 axf).

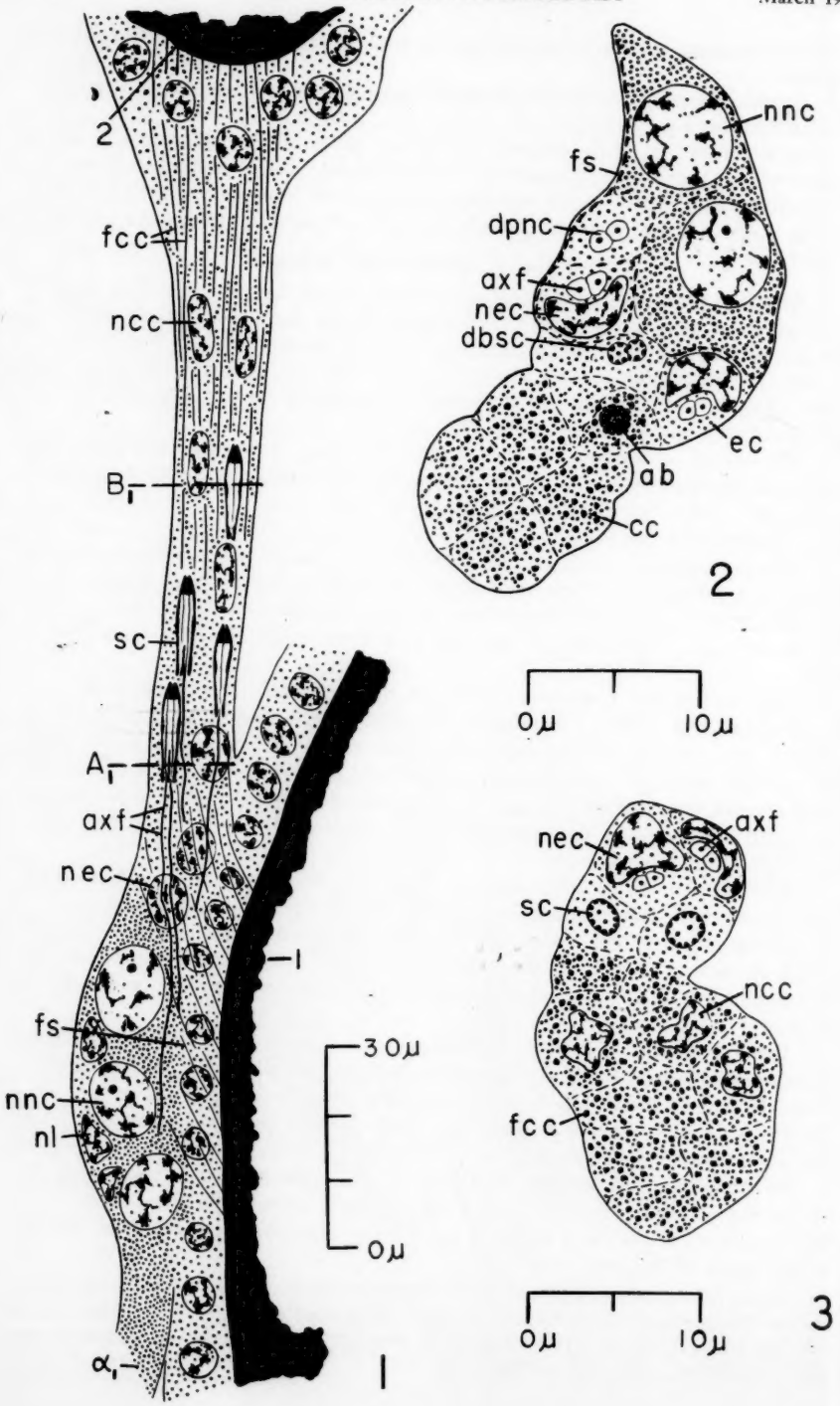
The wall of the cylindrical scolopale is reinforced by a large number of longitudinal ribs which are separate throughout the length of the scolopale (Fig. 3 sc). In the middle and at the base of the scolopale the longitudinal ribs are thickened to form the basal and middle ring-zones (Fig. 1 sc). At the distal end the longitudinal ribs converge to form the conical apex which contains the apical body. At its proximal end the scolopale constricts to form two short cylinders (Fig. 2 dbsc).

The apical body is large, almost completely filling the lumen of the apex (Fig. 2 ab), and dark staining, but lighter than the longitudinal ribs.

Proximally from the apical body run the two fine axial fibers (Figs. 1, 2 axf) which thicken as they leave the scolopale. Each enters the distal process of a nerve cell (Fig. 2 dpnc), and continues in the nerve cell at least as far as the nucleus.

The nerve cell.—There are two nerve cells in a scolopidium of the scapal chordotonal organ. Each nerve cell has a large, ovoid, light staining nucleus (Figs. 1, 2 nnc) and is bipolar: its long distal process receives one of the axial fibers from the scolopale; its short proximal process joins the nerve α_1. The fine distal process is almost invisible in longitudinal section because it is obscured by the enveloping cell which surrounds it. In cross section it appears in the enveloping cell like a vacuole (Fig. 2 dpnc) which contains the axial fiber. The distal processes of the nerve cells are parallel for most of their lengths but diverge in the region of the nerve cell bodies.

The proximal attachment of the scoloparia is made in the region of the nerve cells by supporting cells which have small, dark staining nuclei and contain dark staining fibers (Fig. 2 fs). These cells attach distally to the enveloping cells and proximally to the wall of the scape.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The small, dark staining nuclei closely associated with the nerve cells (Fig. 1 nl) are probably nuclei of the neurilemma or of supporting cells; it is possible that these cells might serve a nervous function (Debauche 1938).

The enveloping cell.—The enveloping cell is elongated with a dark staining nucleus (Fig. 1 nec) situated in the middle of the cell. In longitudinal section the nucleus appears elliptical; in cross section it appears concave on the side facing the distal processes of the nerve cells (Fig. 2 nec).

The cap cell.—The cap cell is slender with an elongated, dark staining nucleus (Fig. 1 ncc) situated at the midpoint of the cell. Each cap cell forms a large number of fibers (Figs. 1, 3 fcc) which surround the apex of the scolopale proximally (Fig. 2), bypass the nucleus which lies in the centre of the cell (Fig. 3) and attach to the cuticula at the base of the pedicel (Fig. 1).

The Organ of Johnston

The organ of Johnston comprises 12 scoloparia distributed in a regular manner around the periphery of the distal half of the pedicel. Proximally each scoloparium is in connection with a branch of the nerve *a* or *b*, and is loosely attached to the epidermis by means of connective tissue. Several scoloparia may be closely associated in the region of the nerve cells, but each scoloparium is innervated independently. Distally the scoloparia diverge, penetrate the epidermis about the level of the midpoint of the organ, and terminate at the articular membrane of the pedicel and third segment in a special manner which will be described.

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1. Longitudinal section of the lateral scapal scoloparium.
2. Cross section of the mesial scapal scoloparium about one-third of the distance from the proximal point of attachment.
3. Cross section of the mesial scapal scoloparium about one-third of the distance from the distal point of attachment.

Abbreviations

ab, apical body
ac, accessory cell
am, articular membrane
anc^2, anterior nerve cells of the subgenual organ
ant, anterior surface
apod, apodeme of flexor of claws
atn, anterior tibial nerve
axf, axial fiber
ba I, dorsal attachment of metathoracic femoral organ
cam, canal in articular membrane
cc, cap cell
cho, chordotonal organ
ct, cuticula
ctc, connective tissue cell
d, dorsal surface
dbsc, double base of scolopale
dfn, dorsal femoral nerve
dpnc, distal process of nerve cell
dsgo, distal subgenual organ
ec, enveloping cell
ecn, epidermal cell nucleus
ext, extensor of tibia
f, femoral wall
fcc, fiber of cap cell
fcc II, fiber of distal cap cell of pedicel organ
fl, flexor of tibia
flp, flexor of pretarsus
fs, supporting fiber
n, nerve
nac, nucleus of accessory cell
nc^1, nerve cells of distal subgenual organ
nc^2, nerve cells of subgenual organ
ncc, nucleus of cap cell
ncc II, nucleus of distal cap cell of pedicel organ
nec, nucleus of enveloping cell
ni, nerve to the integument
nl, nucleus of neurilemma cell
nnc, nucleus of nerve cell
pnc^2, posterior nerve cells of subgenual organ
post, posterior surface
psn, proximal scolopale nerve
ptn, posterior tibial nerve
r, rod
sc, scolopale
sc, scolopale in distal cap cell of pedicel organ
sgn, subgenual nerve
sgo, subgenual organ
tb, terminal bundle
tr, trachea
v, ventral surface
vfn, ventral femoral nerve

Each scoloparium comprises four to seven scolopidia, with all scolopalia situated at about the same level.

Figures 5 to 10 show cross sections of a scoloparium of Johnston's organ cut at the levels A to F of Figure 4.

Microscopic Anatomy

The scolopale.—The scolopale is amphinematic with two axial fibers of the isodynal type, and has a single base. It is smaller than the scolopale of the scapal chordotonal organ.

The longitudinal ribs are fewer but more distinct than those of the scapal organ. Toward the apex of the scolopale the longitudinal ribs become thinner, fuse laterally, and are prolonged to the articular membrane as the terminal bundle (Figs. 4, 8 tb) which gradually narrows as it passes distally. Figure 7 shows scolopalia (sc) cut at different levels; those at the right have been cut toward the base, those at the left near the apex.

The lumen of the tube formed by the terminal bundle is continuous with a fine canal in the articular membrane (Fig. 9 cam). All scolopidia of one scoloparium terminate in the same region of the articular membrane; as the canals move toward the exterior they widen and fuse (Fig. 4) to form a larger canal, which in turn widens progressively.

The apical body is situated at the distal end of the scolopale proper; it is very small and is not usually visible.

Whether a terminal fiber is present is difficult to determine. In cross section, minute rods (Fig. 10 r) can be seen at the base of the canal in the articular membrane; these rods may possibly be homologous with the thickenings at the ends of the terminal fibers in *Meconema varium* Fab. (Debauche 1936) and in *Dociostaurus maroccanus* (Thunb.) (Jannone 1939e). However, the small size and complexity of structures in this region make observation difficult, and it is possible that these rods are artefacts.

Each large canal is protected by the basal end of the third segment which curves inward to form a hollow which fits the contour of the canal (Fig. 4).

Cells of the scolopidium.—The nerve cells of Johnston's organ are bipolar with large, ovoid, light staining nuclei (Figs. 4, 5 nnc). The proximal processes of the nerve cells of each scoloparium unite to form small nerves which in turn fuse to form the two nerves *a* and *b* of the pedicel. The distal processes of two nerve cells, sheathed by a single enveloping cell, run parallely toward the scolopale.

The small, dark staining nuclei in the region of the nerve cell bodies (Fig. 4 nl) probably belong to the neurilemma and connective tissue.

The enveloping cell is elongated with a dark staining nucleus (Figs. 4, 6 nec) situated about midway along the cell.

The cap cell is elongated and surrounds the distal part of the scolopale and the terminal bundle. The nuclei are situated at the proximal ends of the cells (Fig. 4 ncc) and show a marked concavity on the side facing the scolopale (Fig. 7 ncc).

Changes after the molt.—In the newly molted adult insect, the base of the canal in the articular membrane is level with the inner surface of the membrane. As the endocuticula is formed, the epidermis moves toward the interior of the segment. It appears that by the time of molting, the cap cell has lost its ability to add to the cuticula, so that a cavity containing the distal part of the scoloparium is formed in the cuticula (Fig. 4).

The Pedicel Chordotonal Organ

The pedicel chordotonal organ consists of a single scoloparium of five large scolopidia situated in the upper two-thirds of the pedicel (Text Fig. 1 po). It is innervated by branch α_2 of the nerve *a*, and is attached proximally to the base of the pedicel by supporting fibers (Fig. 11), or more loosely to the epidermis by connective tissue. Distally it is held in a hollow in the epidermis, then penetrates the latter, and terminates in a manner identical with that of a scoloparium of Johnston's organ. There are thus 13 canals distributed at more or less regular intervals in the articular membrane of the pedicel and third segment.

Figures 12 to 17 show cross sections of the organ at the levels A^1 to F^1 of Figure 11.

Microscopic Anatomy

The scolopale.—Three scolopalia are situated at about the same level (Fig. 11 sc), the fourth slightly higher, and the fifth (smaller than the others and not shown in this figure) higher still.

The scolopale is similar to that of the scapal organ. It is mononematic, with two axial fibers of the isodynal type (Fig. 11 axf) and has a double base (Fig. 13 dbsc). The longitudinal ribs are numerous and are situated close together (Figs. 13, 14 sc); they thicken and converge at the apex of the scolopale; the basal and middle ring-zones are distinct.

The apical body (Fig. 14 ab) lies at the distal end of the scolopale and appears to be similar to that of the scapal organ. The axial fibers were observed to run proximally as far as the nuclei.

Cells of the scolopidium.—The bipolar nerve cells have large, ovoid, light staining nuclei (Figs. 11, 12 nnc). Their proximal processes form the nerve branch α_2 (Fig. 11); their distal processes sheathe the axial fibers (Figs. 11-15 axf) which penetrate the scolopalia and terminate at the apical body. At the periphery of the ganglion are many small, dark staining nuclei (Figs. 11, 12), some of which belong to the neurilemma (nl), and others to the connective tissue supporting the ganglion.

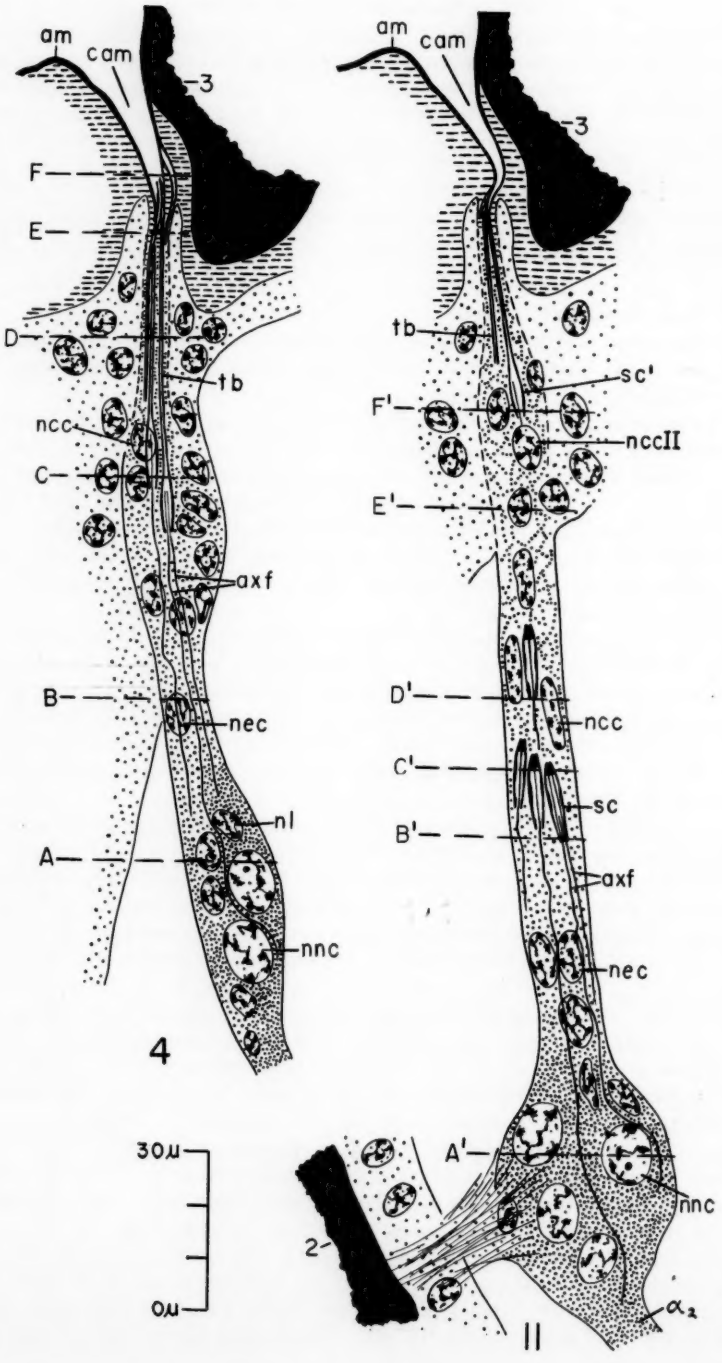
The enveloping cell is elongated with a dark staining nucleus concave on the side facing the nerve cell processes (Fig. 13 nec).

The first cap cell is comparatively short. It surrounds at least the apex of the scolopale (Fig. 14 fcc) and is distally attached to the second cap cell. It has an elongated, dark staining nucleus situated just above the apex of the scolopale in the centre of the cell (Fig. 15 ncc). The cap cell elaborates few fibers (Fig. 15 fcc).

The distal attachment of the organ is made by a second layer of cap cells (Fig. 11 nccII). Several layers of cap cells have been observed in various chordotonal organs, but they have not been described previously as occurring in the pedicel chordotonal organ. Moreover, this cap cell does not resemble the more proximal one, but rather the cap cell of Johnston's organ.

The cap cells II are elongated with dark staining nuclei which resemble the epidermal nuclei (Fig. 11 nccII) and which are situated in the proximal ends of the cells. Distally they end at the articular membrane in a manner identical with the terminations of the cap cells of Johnston's organ (Fig. 11).

The unusual feature of these cells is their possession of scolopalia (Figs. 11, 17 sc) which occur at the proximal ends of the cells just distal to the nuclei. In some cells the scolopalia resemble those of Johnston's organ, having a clear lumen with two fibers; in others, there are only disorganized fibers (Fig. 17 fccII).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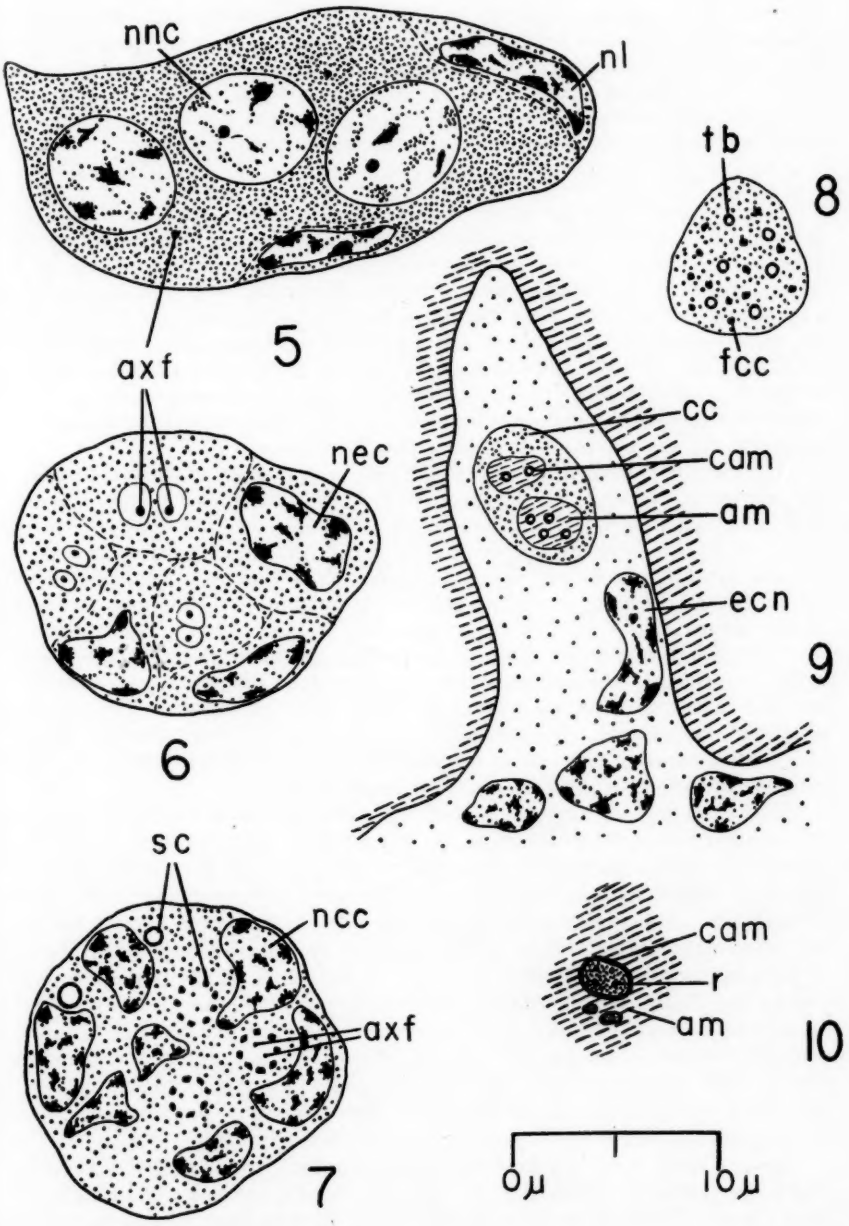


4. Longitudinal section of a scoloparium of Johnston's organ.
5 to 10. Cross sections of a scoloparium of Johnston's organ at the levels A to F of Figure 4.
11. Longitudinal section of the pedicel chordotonal organ.

One specimen presented a somewhat different picture. At the level of the apices of the lower scolopalia of the pedicel organ a small nerve arose from an adjacent scoloparium of Johnston's organ and innervated a small ganglion lying close to the cap cells of the pedicel organ. The ganglion contained the nerve cells of a thirteenth scoloparium of Johnston's organ, in which only two scolopalia were observed. Only one layer of cap cells was present in the pedicel organ, and this tapered distally to attach to the basement membrane.

Discussion

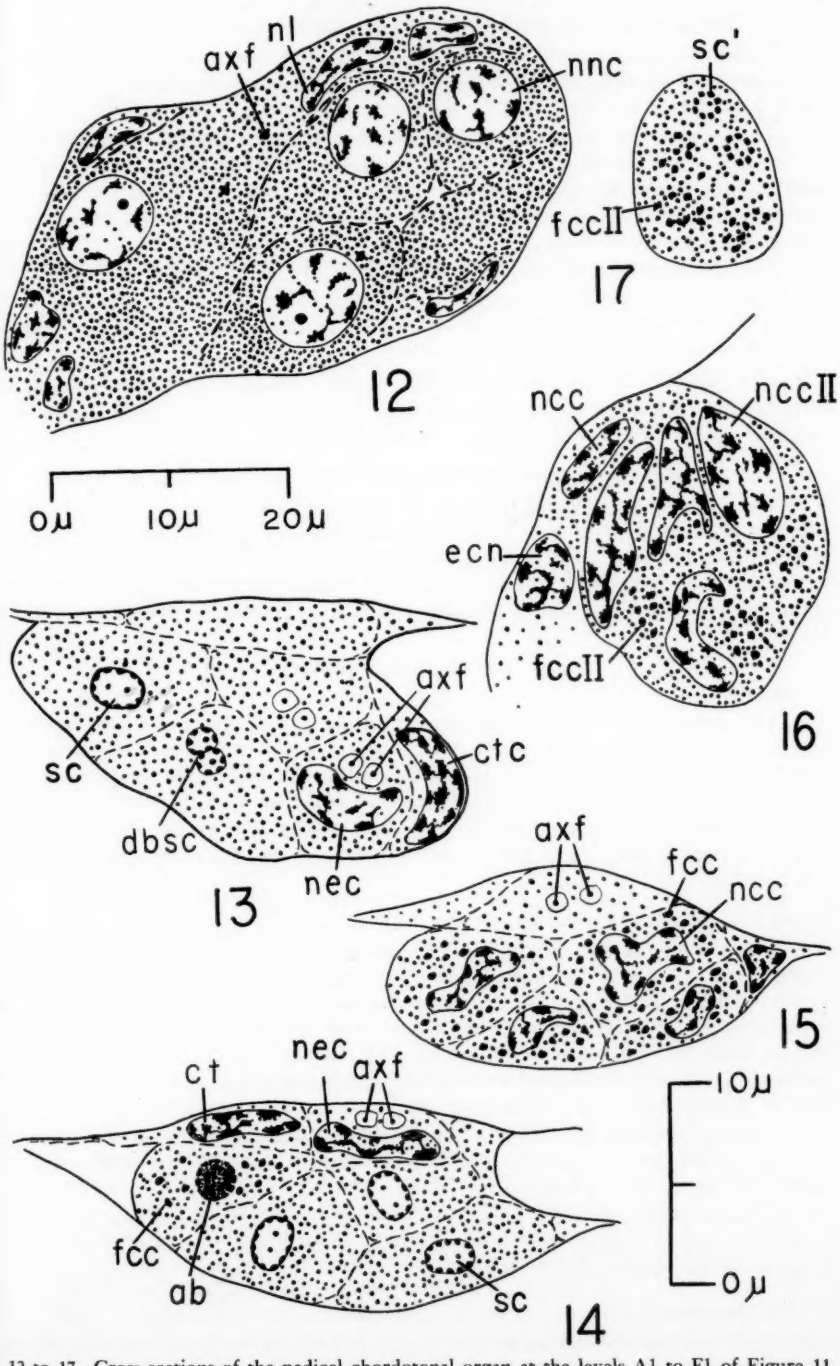
The unusual structure of the pedicel organ presents some evidence concerning the origin of the scolopale. Two opinions are held regarding this question: Snodgrass (1926) and Eggers (1928) consider the scolopale to be formed by the nerve cell; Debauche (1935) believes that it is unlikely that such a specialized cell secretes chitin (although he admits that it is possible in view of the epidermal origin of the nerve cell), and that the scolopale is formed by the enveloping or cap cell. The finding, in this work, of scolopalia lying entirely within the cap cell of the pedicel chordotonal organ lends support to the latter view. It would appear that in embryological development the nerve cell process penetrates the cap cell to come to lie within the scolopale.

On the other hand, the presence of fibers in the lumen of these scolopalia is not necessarily evidence for the formation of the axial fibers by the cap cells. The observation of Sihler in 1924 (Snodgrass 1926), that the axial fiber is not shed at the molt, but remains within the nerve cell, indicates that there is no attachment of the axial fiber to the scolopale. It is difficult to understand how the axial fiber, if formed in the cap cell, could come to lie throughout the length of the nerve cell.

The chordotonal organ of the pedicel of species closely related to *Melanoplus mexicanus* is firmly attached proximally to the wall of the pedicel and distally to the base of the third antennal segment. This firm attachment is characteristic of many mononematic chordotonal organs. It appears, then, that the pedicel chordotonal organ of this species has secondarily lost its distal attachment to the cuticula, and the proximal attachment in many cases.

The extra cap cell might be a modified epidermal cell to which the detached organ has retained its connection, or it may be considered that the pedicel organ has become secondarily attached to the cap cells of a scoloparium of Johnston's organ, with subsequent loss of the nerve and enveloping cells of this scoloparium. Assuming that either of these explanations is the correct one, the structure of the pedicel organs in the particular individual mentioned at the end of the preceding section lends support to the former view; the thirteenth scoloparium had fewer scolopalia than are typical of a scoloparium of Johnston's organ, and its nerve cells lay distal to those of the other scoloparia. It appears that this structure of the pedicel organ represents a further, and almost complete, loss of distal attachment than that which is commonly observed in this insect, and that a new scoloparium of Johnston's organ, incorporating the cap cells II of the pedicel chordotonal organ, has been formed.

Slifer (1936) listed a Johnston's organ, possessing four scolopalia, as occurring in the pedicel of *Melanoplus differentialis*, but did not find a pedicel chordotonal organ. This number of scolopalia closely approximates that in the pedicel chordotonal organ of *Melanoplus mexicanus;* moreover, the characteristic peripheral arrangement of the scoloparia of Johnston's organ was not mentioned; it is possible that the organ Slifer described is similar to the pedicel chordotonal organ of *M. mexicanus.*



12 to 17. Cross scetions of the pedicel chordotonal organ at the levels A^1 to F^1 of Figure 11.

The Chordotonal Organ of the Last Segment of the Antenna

A chordotonal organ consisting of one scolopidium was found in the last or tip segment of the antenna of *Melanoplus differentialis* by Slifer (1936). It has not been reported elsewhere in the literature.

The scolopidium is situated in the upper third of the segment. It is associated proximally with the nerve cells of other sensory endings in a large ganglion attached to the lateral epidermis and innervated by one of the large antennal nerves. The scolopidium runs obliquely to terminate at the central part of the end of the segment.

The scolopale is mononematic, with a single axial fiber, and has a double base.

The enveloping cell surrounds the basal half of the scolopale; it is elongated with a dark staining nucleus which lies at about the midpoint of the cell and is concave on the side facing the axial fiber.

The cap cell sheathes the upper half of the scolopale and makes the distal attachment of the organ. The cap cell nucleus is situated at the basal end of the cell and partially surrounds the apex of the scolopale.

CHORDOTONAL ORGANS OF THE MOUTHPARTS

The scoloparia of the mouthparts of *Melanoplus mexicanus* are identical in number and distribution with those listed by Slifer (1936) for *M. differentialis*. The scoloparia occur only in the labium and maxilla. Those in the labium are situated in the paraglossa and in the second and third segments of the palpus. Those of the maxilla occur in the first and fifth segments of the palpus and in the lacinia.

1. The Labial Scoloparia

Paraglossa

The scoloparium lies in the distal part of the paraglossa, toward the midline, and is stretched across the concave inner surface of the ventral wall. The nerve cells of the two scolopidia are attached basally; the scolopidia separate in the region of the cap cells, and are inserted dorsal and mesial to the nerve cells.

The scolopale is mononematic, with two axial fibers of the isodynal type, and has a double base. The apical body is large; the basal and middle ring-zones are distinct.

Second Segment of the Palpus

The scoloparium is innervated by a branch of the principal nerve of the palpus which arises at the joint of the first and second segments. This nerve, given off in the mesial blood sinus, moves dorsally around the epithelial membrane separating the sinuses into the lateral sinus where it innervates the nerve cells of the scoloparium at a point about one-fifth of the distance up the segment. The scoloparium runs laterally and somewhat ventrally to insert at the extreme distal end of the segment in the midline of the lateral wall.

The scoloparium consists of one or two scolopidia. The scolopale is mononematic with a single axial fiber which runs up the proximal process of the nerve cell for a short distance.

In most palpi studied, a fine nerve accompanied the scoloparium to a level just below the scolopale, then separated at an acute angle to innervate the small organs on the lateral side of the segment.

Third Segment of Palpus

One scolopidium, similar to that in the last segment of the antenna, lies in the distal fifth of the segment.

2. The Maxillary Scoloparia

Lacinia

A large nerve enters the lacinia near the mesial surface and passes laterally to the ventral surface near the base where it innervates the nerve cells of the scoloparia and a small ganglion lying immediately laterad of the nerve cells. A large nerve passes distally from the ganglion.

The nerve cells of the two scoloparia lie side by side dorso-ventrally. The ventrally-lying nerve cells (Scoloparium I) are attached to the epidermis of the ventral wall by connective tissue. Scoloparium I passes mesially and slightly distally to insert on the mesial surface of the lacinia; the scolopidia lie side by side, forming a sheet of cells. Scoloparium II runs distally to attach to the epidermis of the ventral surface about one-fifth up the lacinia; the scolopidia are loosely associated distally.

The scolopalia are mononematic with two axial fibers of the isodynal type.

First (Basal) Segment of Palpus

The nerve cells are attached to the epidermis of the ventral surface near the base of the segment. The scoloparium moves distally, laterally, and ventrally. It attaches to the epidermis about half-way up the segment, then runs along the surface to terminate at the joint of the first and second segments.

The scoloparium comprises five scolopidia. The scolopalia are mononematic with a single axial fiber.

Fifth Segment of Palpus

The single scolopidium is similar to that found in the third segment of the labial palpus.

CHORDOTONAL ORGANS OF THE LEGS

Terminology

The terminology used is that followed by Slifer (1935) and Debaisieux (1934; 1938). The legs are oriented after the convention suggested by Grimshaw in 1908 (Debaisieux 1938). The leg is considered to lie horizontal and perpendicular to the longitudinal axis of the body. All segments of the leg lie in the same plane, so orientation is constant from one segment to the next.

Innervation of the Chordotonal Organs of the Pro- and Mesothoracic Legs

An account of the innervation of the pro-and mesothoracic chordotonal organs of *Mecostethus grossus* L. given by Debaisieux (1938) applies almost equally well to *Melanoplus mexicanus*. The description given below applies also to the tibial and tarsal organs of the metathoracic leg. The innervation of the metathoracic femoral organ, however, is different, and will be discussed separately.

A large nerve enters the base of the leg and divides in the coxa into two large trunks which pass into the femur as the dorsal femoral nerve (dfn), lying anteriorly, and the ventral femoral nerve (vfn), lying posteriorly (Text Fig. 2A).

Just before entering the femur, the dorsal femoral nerve gives off the proximal scolopale nerve (psn) which innervates the aggregated femoral scoloparium (afs). A small branch (not shown) of the proximal scolopale nerve continues along the ventral surface of the aggregated femoral scoloparium to innervate Bundle II of the dispersed femoral scoloparium (dfs). The dorsal femoral nerve in passing down the femur gives off a second branch, to Bundle II of the dispersed scoloparium, then moves into the ventral blood sinus and enters the tibia as the subgenual nerve (sgn).

The subgenual nerve moves into the dorsal blood sinus along the anterior surface of the tibia, innervates the subgenual and distal subgenual organs (sgo; dsgo), and ends at the small integumentary sense organs in this region.

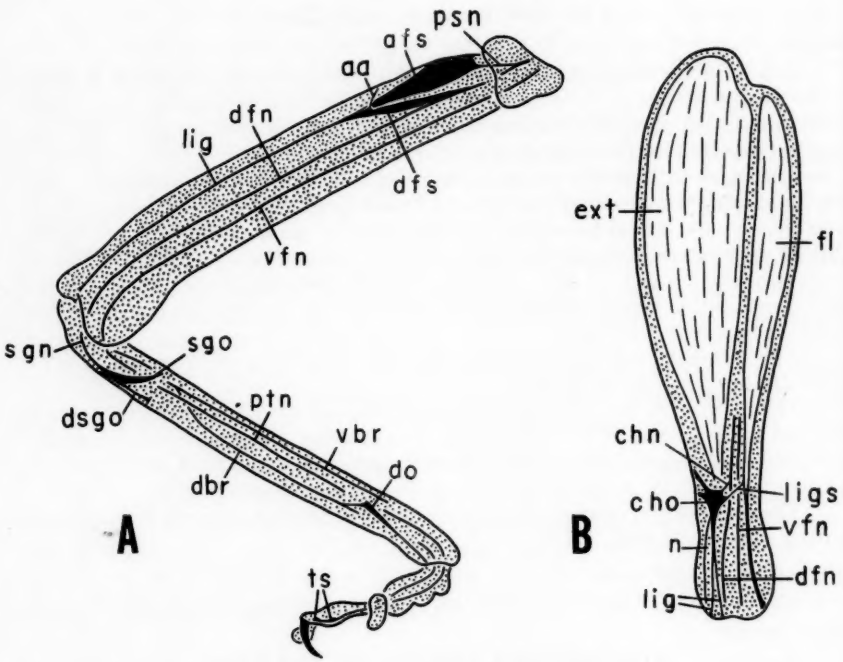


Fig. 2. A, anterior view of right prothoracic leg; B, anterior view of right metathoracic femur. aa, anterior attachment of dispersed femoral scoloparium; afs, aggregated femoral scoloparium; chn, chordotonal nerve; cho, chordotonal organ; dbr, dorsal branch of anterior tibial nerve; dfn, dorsal femoral nerve; dfs, dispersed femoral scoloparium; do, distal organ of the tibia; dsgo, distal subgenual organ; ext, extensor of the tibia; fl, flexor of the tibia; lig, chordotonal ligament; ligs, supporting ligament of metathoracic femoral organ; n, nerve from metathoracic femoral organ; psn, proximal scolopale nerve; ptn, posterior tibial nerve; sgn, subgenual nerve; sgo, subgenual organ; ts, tarsal scoloparia; vbr, ventral branch of anterior tibial nerve; vfn, ventral femoral nerve.

The ventral femoral nerve divided on entering the tibia into two main branches, the anterior and posterior tibial nerves (atn; ptn).

The posterior tibial nerve remains throughout its course along the posterior surface of the tibia in the ventral blood sinus, and enters the tarsus.

The anterior tibial nerve bifurcates a short distance down the tibia from the subgenual organ. The dorsal branch (dbr) passes into the dorsal blood sinus, gives off a small nerve which is directed ventrally to the distal tibial organ (do), and continues into the tarsus where it innervates the tarsal scoloparia (ts). The ventral branch (vbr) breaks up in the ventral blood sinus, innervating the muscles of the tarsus and pretarsus and other structures in this region.

The Pro- and Mesothoracic Femoral Chordotonal Organs

The chordotonal organs of the pro- and mesothoracic femora are identical with regard to structure and innervation. Each consists of two large scoloparia, designated proximal and distal by Slifer (1935), and condensé et dispersé by Debaisieux (1938). Debaisieux has found that while two scoloparia occur in most insect femora, they do not always have the distinct proximal-distal relationship which is apparent in some insects (including *Melanoplus mexicanus*). A more constant difference is the arrangement of the scolopalia: in one scoloparium,

they are more or less restricted to a certain region (condensé); in the other, they are distributed throughout the length of the scoloparium (dispersé). In order to preserve this distinction, the terms "aggregated" and "dispersed" will be used in this work.

1. The Aggregated Femoral Scoloparium

The aggregated femoral scoloparium grossly resembles a capitate cylinder extending the length of the femur, with its large proximal end attached to the antero-dorsal wall near the base of the femur (Text Fig. 2A) and with its distal insertion on the articular membrane of the femur and tibia just anterior to the insertion of the extensor of the tibia.It is sheathed by a membrane which is continuous with the basement membrane.

Microscopic Anatomy

The histological elements are arranged in a series of regular layers (Fig. 18): the nerve cells lie basally, followed by the enveloping cells, scolopalia and cap cells; the central scolopidia lie higher up. This arrangement is also illustrated in Figure 23, in which the enveloping cells lie within a peripheral cover of nerve cells, and in Figure 24, in which the scolopalia lie near the centre, surrounded by enveloping cells, which in turn are sheathed by the nerve cells.

The number of scolopidia varies, but on the average there are 240 in each of the pro- and mesothoracic scoloparia.

Figures 23 to 25 illustrate cross sections of the scoloparium at the levels A_1 to C_1 of Figure 18.

The scolopale.—The scolopale is mononematic with two axial fibers of the isodynal type, and has a double base (Fig. 24 dbsc).

The longitudinal ribs are quite thin and appear to fuse laterally to form a homogeneous border around the cavity of the scolopale. Only at the proximal end, where they form the double base, do they appear to separate. The longitudinal ribs are thickened at the apex of the scolopale, and at the base and in the middle to form the basal and middle ring-zones.

The apical body is large, dark staining, filling the lumen of the apex, and appears to be attached to the longitudinal ribs.

The cap cell and chordotonal ligament.—The cap cells form three distinct layers of approximately equal length. The transition between layers is marked by numerous short, stout, dark staining fibers which presumably reinforce the attachment of the ends of the cells.

The cap cells of the basal layer are elongated with elongated nuclei lying at the proximal ends of the cells (Fig. 18 ncc). They elaborate many thick fibers (Fig. 18 fcc).

The cap cells of the second (Fig. 26) and third layers are fewer and of greater size than those of the first. The nuclei are elongated but are not concentrated at the end of the cells. Short fibers similar to those of the transition can be seen throughout these layers; it is probable that these layers are several cells in length.

At the distal end of the third layer the cap cells surround and insert upon the chordotonal ligament. Superficially the transition from cap cells to chordotonal ligament is rather gradual; the nuclei become fusiform and the cells spindle-shaped and closely packed, and the whole much narrower. In cross section (Fig. 28), the ligament is seen to have a cuticular core (ct) sheathed by epidermal cells (ecn). The sheath is continuous with the epidermis and the cuticular core with the wall of the leg. The ligament comprises over half the length of the entire scoloparium.

2. The Dispersed Femoral Scoloparium

The dispersed scoloparium is narrow, flattened (Fig. 27), and lies distal, anterior, and ventral to the aggregated scoloparium. It is attached to the anterior wall of the femur by a fine strand of cells (Text Fig. 2A aa) and joins the aggregated scoloparium distally about the level of the third layer of cap cells.

The dispersed scoloparium consists of two closely associated bundles of scolopidia, distinguished only by their separate innervation. Bundle I (Fig. 27 I) is the larger. It is innervated by a branch of the dorsal femoral nerve at about the level of the first layer of cap cells of the aggregated scoloparium. Bundle II (Fig. 27 II) lies along the ventral margin of Bundle I, and is innervated by a branch of the proximal scolopale nerve (Figs. 23, 24 n).

Microscopic Anatomy

The histological elements are similar to those of the aggregated scoloparium. There are approximately 16 to 21 scolopidia, and only one layer of cap cells. The random distribution of the elements may be inferred from Figure 27, which shows the occurrence of almost all of the diverse elements at the same level.

The Metathoracic Femoral Chordotonal Organ

Gross Anatomy and Innervation

The metathoracic organ consists of a single scoloparium, greatly flattened antero-posteriorly, situated in the antero-dorsal corner of the distal sixth of the femur (Text Fig. 2B; Fig. 19 cho). The scoloparium is attached to the dorsal wall of the leg by two bands of cells (Text Fig. 2B). In cross section of the femur (Fig. 19), band I (ba I) can be seen running directly dorsad to attach to the epidermis, while band II, running proximally, dorsally and posteriorly, forms the connection of the second dorsal arm (shown in this figure) with the median dorsal body wall. The anterior attachment of the organ is made by a fine band of cells which arises from the ventral proximal anterior surface and attaches to the epidermis of the anterior wall of the femur (Fig. 19).

Two large nerves enter the metathoracic femur, the dorsal and ventral femoral nerves (Text Fig. 2B dfn; vfn), which lie in the dorsal blood sinus. At a point about five-sixths of the distance down the segment the chordotonal nerve (Text Fig. 2B chn) leaves the dorsal femoral nerve and moves dorsally and anteriorly to innervate the metathoracic chordotonal organ.

A supporting ligament (Text Fig. 2B ligs) arises from the mid-dorsal surface of the apodeme of the flexor of the tibia (fl) and moves laterally and dorsally, paralleling the course of the chordotonal nerve, to attach to the organ at a point just distal to the connection of the nerve.

The scoloparium is attached to the articular membrane of the femur and tibia by two ligaments (Text Fig. 2B lig), identical in structure with that of the pro- and mesothoracic organs. Another distal attachment is made, possibly, by a fine band of cells which leaves the ventral surface of the organ near the attachment of the supporting ligament and is directed ventrally. However, its insertion was not found.

One large nerve (Text Fig. 2B; Figs. 20, 21 n) arises from the anterior surface of scoloparium and passes distally down the femur.

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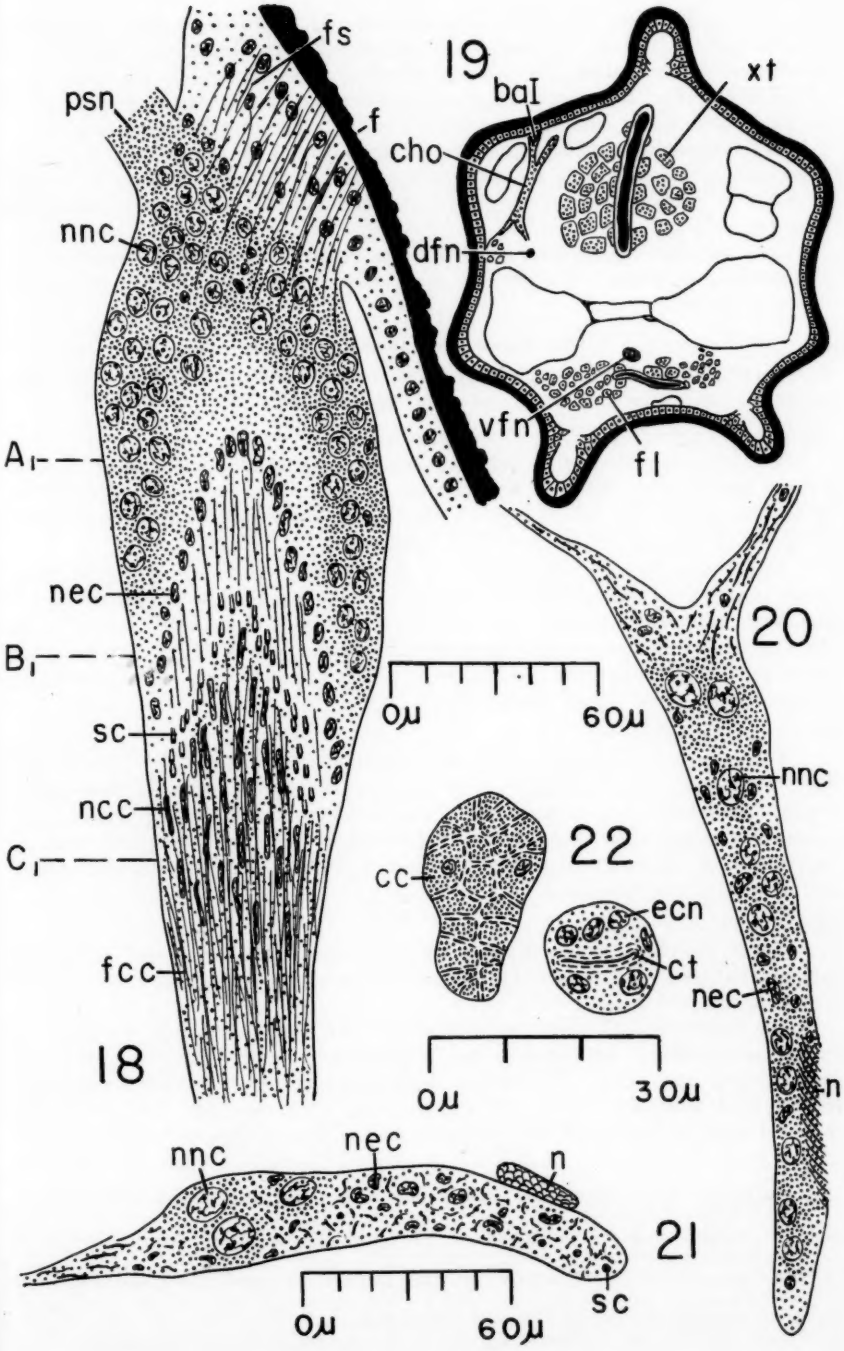
18. The basal region of the aggregated femoral scoloparium as seen in frontal longitudinal section of the prothoracic femur.
19. Cross section near to the distal end of the metathoracic femur showing the location of the chordotonal organ.
20. Cross section of the metathoracic femoral chordotonal organ near to the proximal end.
21. Cross section near to the middle of the metathoracic femoral chordotonal organ.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Microscopic Anatomy

The scoloparium comprises approximately 32 scolopidia. The distribution of scolopalia is not so random as in the dispersed scoloparium; generally all scolopolia occur at about the same level. In a cross section of the upper part of the organ (Fig. 20), nerve cell nuclei predominate. The darker nuclei belong to the neurilemma. The large nerve (n) is just separating from the organ.

A section at about the midpoint of the main part of the organ (Fig. 21) shows principally enveloping cells and scolopalia. The scolopidia with nerve cells lying in the more ventral part of the organ run obliquely dorsad to join the chordotonal ligament.

The cap cells divide into approximately equal bundles which attach to the chordotonal ligaments. In Figure 22 the cap cell bundle and ligament are shown in cross section.

The Tibial Chordotonal Organs

Each tibia contains three chordotonal organs which are similar in all legs: the subgenual, distal subgenual and distal tibial organs.

1. *The Subgenual and Distal Subgenual Organs*

The tibia is divided proximally into two blood sinuses, dorsal and ventral, by a large trachea (Fig. 30 tr). Both organs lie entirely in the dorsal sinus in the basal sixth of the tibia (Text Fig. 2A sgo; dsgo). Their nerve cells lie together along the dorso-anterior surface of the tibial wall.

The innervation of the organs is shown in Figure 33. The subgenual nerve (sgn) in the dorsal sinus divides into two short branches: the dorsal branch innervates the more posterior nerve cells of the subgenual organ (pnc^2), while the ventral branch innervates the distal subgenual organ and the more anterior nerve cells of the subgenual organ (anc^2). Both branches give off nerves to the integumentary sense organs in this region (ni).

a) *The Subgenal Organ*

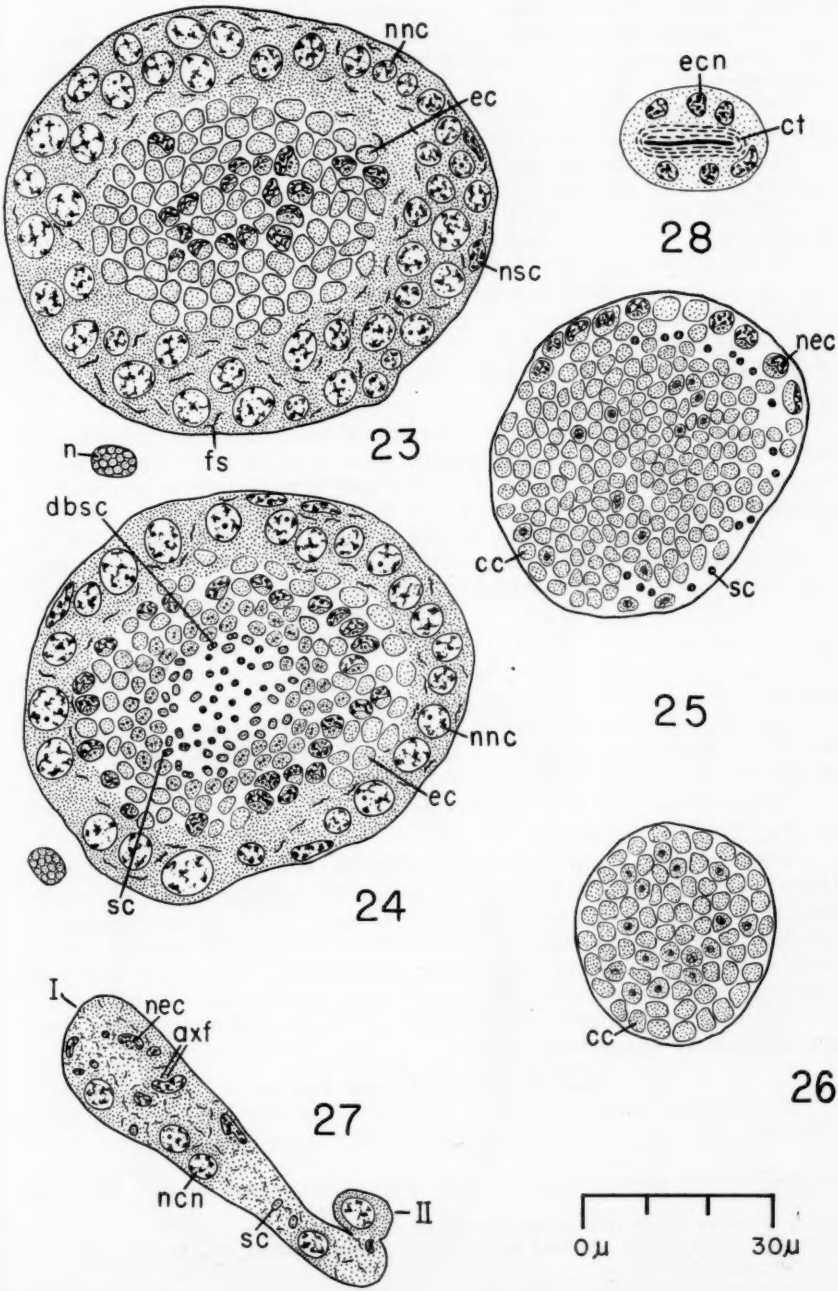
The subgenual organ has a roughly triangular shape (Text Fig. 2A sgo; Fig. 29). Proximally its nerve cells are associated with those of the distal subgenual organ. Its dorsal edge is attached to the basement membrane of the concave dorsal wall of the tibia (Fig. 30 sgo). The organ thins out as it passes distally, and inserts on the posterior wall of the tibia at a point which would correspond to the apex of the triangle.

Microscopic Anatomy

Figure 29 shows a longitudinal section through the subgenual and distal subgenual organs, and Figure 31 a cross section of the subgenual organ in the region of the scolopalia.

The scolopale.—There are approximately 19 scolopalia in the prothoracic, 22 in the mesothoracic, and nine in the metathoracic organ. The scolopalia are mononematic and smaller than those of the femoral organs. They have either one or two axial fibers (Fig. 31 sc); in those with two, the axial fibers are isodynal and the scolopale has a double base. The scolopalia with two axial

22. Cross section of the metathoracic femoral chordotonal organ in the region of the cap cells and chordotonal ligament.
23 to 25. Cross sections of the aggregated femoral scoloparium at the levels A_1 to C_1 of Figure 18.
26. Cross section of the aggregated femoral scoloparium in the region of the second layer of cap cells.
27. Cross section of the dispersed femoral scoloparium.
28. Cross section of the chordotonal ligament of the aggregated femoral scoloparium.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fibers are usually situated in the middle of the organ (Fig. 31). The apical body is large, and the basal and middle ring-zones are distinct.

Cells of the Scolopidium.—The nerve cells are grouped into two more or less distinct masses, one mass lying slightly proximal, ventral and anterior to the other.

The enveloping cells are elongated with small dark staining nuclei (Figs. 29, 31 nec) which appear concave in cross section in the region of the axial fibers.

The cap cells are long and tapering, and contain many fibers which attach to the cuticula of the posterior wall of the leg. There appears to be only one layer of cap cells, although Debaisieux (1938) has found several layers in the same organ of *Mecostethus grossus*.

In the middle region of the concave upper surface of the organ is a large cushion of accessory cells with dark staining nuclei of various shapes and sizes (Figs. 29, 31 nac). The cells are attached proximally to the underlying scolopidia, but distally the mass thins out and inserts separately at the cuticula just above the insertion of the subgenual organ.

b) *The Distal Subgenal Organ*

The distal subgenual organ lies along the anterior surface of the tibia (Text Fig. 2A dsgo; Fig. 29). Its spindle-shaped mass of nerve cells (Fig. 29 nc[1]) lies ventral to, and immediately distad of, the ventral nerve cells of the subgenual organ, and is attached to the anterior wall of the tibia by connective tissue (Fig. 29). The organ is inserted in the anterior part of a sheet of accessory cells (Fig. 29 ac) which forms a barrier across the anterior half of the dorsal sinus, being attached to the trachea by connective tissue and to the anterior and dorsal walls of the tibia.

Microscopic Anatomy

There are approximately 12 scolopidia in the pro- and mesothoracic organs and six in the metathoracic organ.

The scolopidia are arranged in a double row (Fig. 32) with all scolopalia situated at about the same level. The histological elements are similar to those of the subgenual organ, but all scolopalia have single axial fibers (Fig. 32 axf).

The accessory cells are large, fibrillar cells with small, dark staining nuclei.

2. *The Distal Tibial Organ*

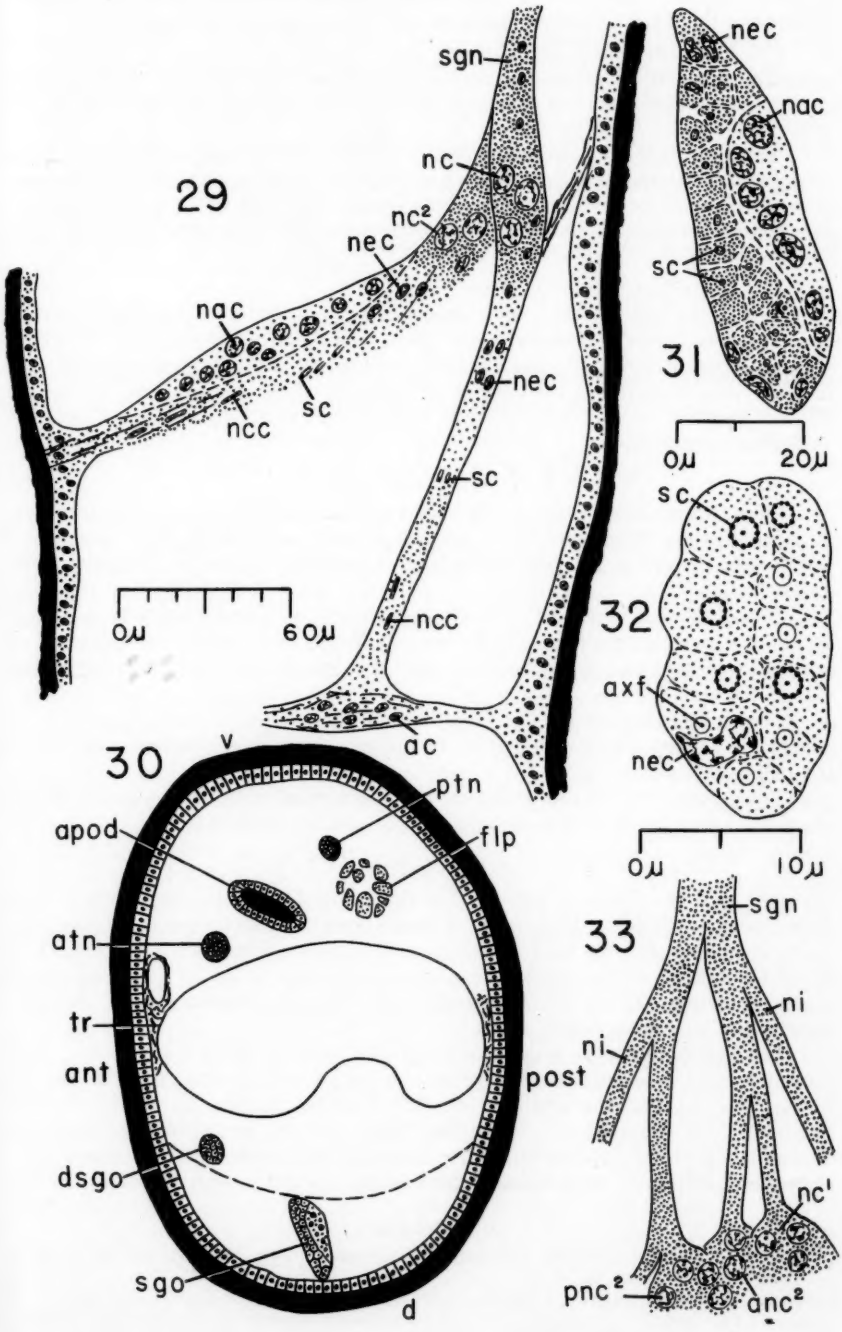
The distal tibial organ lies in the distal fourth of the tibia (Text Fig. 2A do). It is attached proximally to the posterior surface of the trachea, and runs between the trachea and the extensor of the tarsus, entering the dorsal sinus posterior to the dorsal branch of the anterior tibial nerve, to insert in the epidermis immediately above the insertion of the extensor of the tarsus. The organ is long and tapering, and is innervated by the dorsal branch of the anterior tibial nerve.

There are approximately nine scolopidia in the pro- and mesothoracic organs, and three in the metathoracic organ.

The Tarsal Chordotonal Organs

The anterior tarsal nerve gives off several branches in the region of the proximal tarsal scoloparium, one of which divides almost immediately to provide

29. The subgenual organs as seen in transverse longitudinal section of the right mesothoracic tibia.
30. Cross section of the tibia in the region of the subgenual organs.
31. Cross section of the subgenual organ of the right prothoracic tibia at the level of the scolopalia.
32. Cross section of the distal subgenual organ of the right prothoracic tibia at the level of the scolopalia.
33. Diagram showing the innervation of the subgenual organs by the subgenual nerve.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a nerve for the scoloparium. The main branch continues into the pretarsus, innervates the distal tarsal scoloparium, and passes into the arolium.

1. *The Proximal Tarsal Scoloparium*

The proximal tarsal scoloparium is situated at the distal end of the anterior wall of the third tarsal segment proper, and is inserted on the wall of the pretarsus.

The histological elements are similar to those of the subgenual organ. The scoloparium comprises two or three scolopidia. The scolopalia are mononematic; the apical body is large; the middle and basal ring-zones are distinct; and the number of axial fibers is either one or two. The cap cells make the distal attachment of the organ.

2. *The Distal Tarsal Scoloparium*

The nerve cells of the distal tarsal scoloparium lie in the proximal part of the pretarsus, above the unguitractor plate, and slightly proximal to the claws. The scoloparium breaks up distally into two divergent bundles of scolopidia; the anterior bundle inserts at the base of the anterior claw, the posterior at the base of the posterior claw. The anterior bundle contains two scolopidia and the posterior bundle one.

Summary

Four chordotonal organs occur in the antenna of *Melanoplus mexicanus*: one is situated in the scape; two, the organ of Johnston and the pedicel chordotonal organ, are situated in the pedicel; and the fourth lies in the last segment of the antenna.

The distal attachment of the pedicel chordotonal organ is made by a second layer of cap cells which resemble those of Johnston's organ; the presence of scolopalia within these cells is evidence for the origin of the scolopale from the cap cell of the scolopidium.

Chordotonal organs are distributed in the mouthparts as follows: one in the paraglossa and two in the palpus of the labium; two in the lacinia and two in the palpus of the maxilla.

The femur, tibia and tarsus of the leg contain chordotonal organs similar to those described by various authors for other species of Acrididae.

Acknowledgments

The author wishes to express his thanks to Dr. L. G. Saunders, of the Department of Biology, University of Saskatchewan, under whose direction this work was done, for his kind assistance and advice. The author is grateful to Dr. J. G. Rempel of the University of Saskatchewan for his encouragement and continued interest in the problem, and to Mr. Norman Ferrier, also of the University, for his photographic work.

The grasshoppers were collected with the help of Mr. Elmer Peters. The comments and assistance on technical matters of Mr. Peters, and of Mr. A. Brooks, Mr. L. Putnam, and the late Mr. Herman Moore, all of the Federal Laboratory of Entomology, Saskatoon, Saskatchewan, are greatly appreciated. The author is grateful also to Dr. G. Fraenkel and the Department of Entomology, University of Illinois, for providing the facilities for the completion of this work.

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Biology of *Bracon cephi* (Gahan) (Hymenoptera: Braconidae), An Important Native Parasite of the Wheat Stem Sawfly, *Cephus cinctus* Nort. (Hymenoptera: Cephidae), in Western Canada[1]

By W. A. Nelson[2] and C. W. Farstad[3]

Introduction

During the past 25 years the wheat stem sawfly, *Cephus cinctus* Nort., has become one of the most destructive pests of wheat in the Prairie Provinces. Annual losses in the wheat-growing area of Saskatchewan have been estimated as high as 17 million bushels (King and McDonald, 1944). There are, however, several native parasites of this pest, and of these *Bracon cephi* (Gahan) [*Microbracon cephi* Gahan] is the most important. In some areas this parasite has been very effective in reducing severe sawfly infestations.

The biology of *B. cephi* was studied each season from 1943 to 1947. Concentrated study was conducted at Rockyford, Alberta, in 1943 and 1944 and at Aylesbury, Saskatchewan, in 1946 and 1947. Although previous to 1943 no definite project had been undertaken, much information had been accumulated during 15 years of research in the cultural control of the wheat stem sawfly.

The life-history of the wheat stem sawfly has been described by Ainslie (1920) and Criddle (1922). Adults emerge about the middle of June and lay their eggs inside the stems of wheat. During July and part of August, the developing larva feeds on the inner layers of plant tissue, hollowing out most of the stem. As the wheat begins to ripen, the larva retires to the base of the stem and girdles it with a V-shaped notch about ground level. This so weakens the stem that it breaks off at that point. The larva in the stub thus formed plugs the open end with frass and spins a transparent hibernaculum, which lines the inside of the stub. The mature larva spends the winter in the stub and pupates in the latter part of May or early June.

Methods

Mature and almost mature larvae, as well as pupae, of *B. cephi* are easy to rear to adults at constant temperatures and relative humidities in the laboratory. It was impossible, however, to rear immature larvae in this manner.

Ovaries were examined quickly in the following manner. Female parasites were dissected under water in the field and in the laboratory by pulling off the

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ovipositor and terminal abdominal segments with forceps. A binocular dissecting microscope was used at all times. It was noted year by year that oviposition commenced shortly after the more mature eggs in the ovary took on a faint yellowish tinge. These eggs were arbitrarily termed *mature*.

Parasite abundance was usually studied during spring and fall sawfly surveys. In the fall the mortality due to parasitism was recorded along with infestation and damage data, and in June the number of adult parasites and sawflies taken in a standard number of sweeps with the net was recorded.

Observations on activity of adult parasites were made in the field. Oviposition habits were studied also by watching a female parasite enclosed with a "windowed" stub in a vial. A standard number of sweeps under a variety of field conditions was found to provide an index of the abundance and activity.

Life-History of *Bracon cephi*

The life-history of *B. cephi* is similar to that of *Bracon terebella* (Wesm.), [*Microbracon terebella* Wesm.] whose habits were described by Salt (1931). It is an external larval parasite whose larval period is spent on the integument of the host.

Fig. 1 illustrates the life-history.

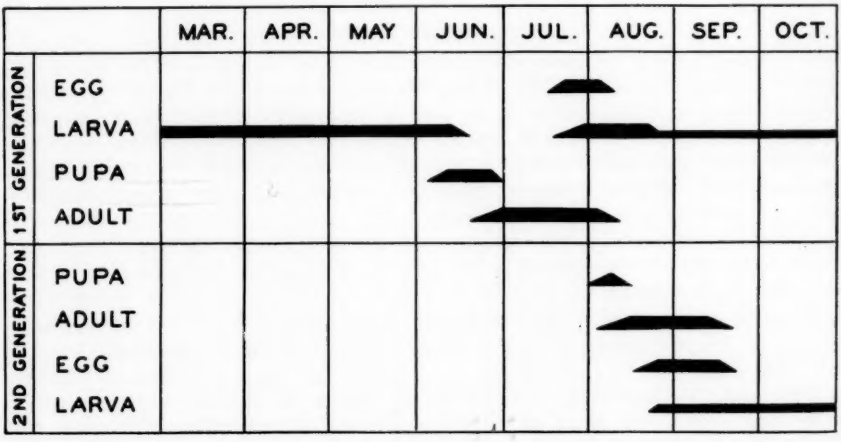

Fig. 1. Life-history chart of *Bracon cephi* (Gahan).

Egg and Larva

The egg is very pale yellow, elongate, and enlarged at the anterior end. The average length is 0.86 mm. The eggs are laid on or near the host. Only one egg is laid for each host, and only one individual develops from each egg. The incubation period varies from one to two days.

The newly hatched larva is about one millimetre in length. There appear to be five instars. In the first three instars the larva has a measurable head-capsule, but in the last two the head becomes merely a button-like disc. The head of the first-instar larva is very prominent, being proportionately larger in relation to the body than in any of the succeeding instars. The newly hatched larva is very delicate and translucent. In later instars the colour changes to brownish. In the later instars, white irregular bodies close to the skin are very conspicuous; they resemble the urate cells described by Cherian and Narayanaswami (1944).

The larva has 13 body segments. In the first instar a band of setae encircles each segment except the last two; there are also two transverse ventral folds on each segment except the first, twelfth, and thirteenth. No appendages, except a pair of non-segmented antennae, are conspicuous in any larval stage. The mouth parts are strongly sclerotized; the mandibles are well developed. The tracheal system is present in each instar. In the first instar spiracles are present on all except the second, third, twelfth, and thirteenth segments.

The newly hatched larva, upon locating its host, attaches itself by means of its mandibles and immediately begins to feed, writhing in the process. The act of moulting was not observed. When feeding is complete, usually little is left of the host but the integument. The fully grown larva spins a cocoon inside the stem, the process taking a day or two. The cocoon is cylindrical and is held firmly in place in the stem by a disc-like plate at each end. These plates are spun first in the construction of the cocoon and determine its length. Cocoons vary in colour from pure white to light brown. Early cocoons of the first generation are often very flimsy and are not always cylindrical, being mere coverings that secure the larvae to one side of the stem wall. Adults emerging from these cocoons are small and atypical. It is suggested that the eggs have been laid on small hosts and that the larvae have had insufficient food to complete their normal development, the resulting adults being abnormal in size and coloration. The larval stage, from hatching to spinning of the cocoon, lasts about ten days.

Larvae removed from cocoons are somewhat smaller than last-instar larvae prior to spinning of the cocoon. This reduction in size may be attributed to two things: the utilization of stored material in the construction of the cocoon, and the excretion of the larval meconium. At this stage the larva becomes somewhat flattened dorsoventrally and develops prominent hypopleural swellings. It becomes pale yellow and the urate cells become less conspicuous.

The winter is passed as a mature larva in the cocoon.

Prepupa and Pupa

The prepupal stage is readily recognizable by the constriction in the body behind the third thoracic segment. Immediately prior to this change the larva becomes more active within the cocoon. The developing appendages become clearly visible through the cuticle, and eye coloration is evident before the final ecdysis. The duration of this stage in the laboratory at 25°C. and 70 per cent R.H. was about two days.

The newly formed pupa is delicate, white, with eyes generally turning pink. Pupation takes place within the cocoon, but individuals will pupate normally if removed. The pupa is free but is incapable of any movement. The duration of this stage in the laboratory at 25°C. and 70 per cent R.H. was about six days.

Adult

Emergence and Longevity

Transformation from pupa to adult requires but a few hours, and individuals rest as adults in the cocoons until the cuticle has hardened. Most commonly the insect emerges by chewing a neat, circular hole through the walls of cocoon and stem, escaping directly from the cocoon to the exterior. Less commonly, however, the adult may escape from the end of the cocoon into the lumen of the stem; then it escapes from the stem at another point, also by chewing a hole in the stem wall. Occasionally, small individuals escaping by the latter method become trapped in the stem and die.

The sex ratio of first-generation adults was calculated for 110 individuals that emerged in the laboratory. For these, the ratio of males to females was

1:1.34. For 31 second-generation adults, the ratio of males to females was 1:0.48.

Females always outlive the males. In the laboratory, all males died from ten to 14 days after they emerged, and females within four weeks. In the field, males begin to emerge during the first week in June and may be found up to the end of July. Females begin to emerge in the last week of June and may still be found when the second-generation females appear about the middle of August. The life span of adults of the second generation appears to be similar to that of the first, except that second-generation females are subject to adverse weather in some districts near the end of September. In 1944 at Rockyford, females were found from the middle of August to September 28. At that time a frost was assumed to have caused their death, for none could be found under ideal conditions prevailing four days later.

Feeding and Locomotion

It seems most likely that the adults feed on droplet moisture present on leaves. They have been observed feeding on the nectar of small flowers along headlands and roadsides. Adults kept dry in a flask for a number of days quickly approached moistened cotton and imbibed either water or sugar solution.

The adults walk up and down the stems and leaves. In searching for a host larva, a female may traverse the length of a stem many times. *B. cephi* resembles *C. cinctus* in that it flits from stem to stem. It can fly for considerable periods and, on a very calm day, may be observed flying above the crop, but with no specific directional tendency. Wind velocity has a decided effect on flight: As the velocity increases, the degree of activity decreases, until in strong winds it is almost impossible to obtain adults by sweeping because they seek shelter near the ground, clinging to the undersides of leaves.

Responses to Light and Temperature

Adults of *B. cephi* are positively phototactic. When enclosed in a tube, they congregate at the end nearest the light source and move to the opposite end if the tube is reversed. In the field, only small numbers can be taken on cloudy days or toward dusk of a normal day, whether warm or cool.

During cool weather activity is greatly reduced; adults become sluggish and cannot be taken by sweeping. Hot, dry weather, common on the prairies, also reduces activity; and if such conditions continue for many days many adults die. Activity, especially oviposition, is more pronounced in bright sunshine after a shower than in a hot, dry atmosphere. In one instance at Rockyford in 1943, within three days after a rain parasitism increased from 20 to 50 per cent. Maximum activity occurs at approximately 70° to 80°F.

Oviposition

There is a preoviposition period of about three weeks in the first generation.

B. cephi must locate its host, paralyse it, and deposit its egg. While walking up and down the stem, the female parasite was observed to stop periodically and straddle the stem with the antennae, remaining in this position for several seconds. Obviously, this procedure assists her in locating the host. A similar phenomenon has been noted by Krishna Ayyar (1943). Laboratory observations showed that when she finds the general position, she inserts her ovipositor into the stem, and when the host passes by she stings it, paralysis following in a few seconds. In all studies conducted by the writers, only one instance has been observed in which there were two eggs close to one host.

Because of the cannibalistic habits of the host larva and the sluggishness of the parasite larva, the host must be paralysed in order that the parasite may

survive. Paralysis of the host is achieved apparently by the injection of some toxic material (Clausen, 1940). If the tip of the ovipositor fails to obtain firm contact with the cuticle, it will slide off and the host will immediately move away. Often the parasite then keeps its ovipositor inserted in the same place, awaiting the chance return of the host. She may, however, change her position on the stem and make a new insertion.

The egg is not attached to, and not necessarily laid on, the host and may be found anywhere within five centimetres of the host larva. If the onset of paralysis of the host is slow, it may have some chance to move a little distance before paralysis is complete. Hence, even if the egg is laid at the same point in the stem where the ovipositor has been inserted to paralyse the host, in many instances the parasite larva has to search for its host.

Although the subject will be discussed in more detail in a later paper, it is worth while here to mention the relation of the texture of the stem containing the host to oviposition. It was observed that the percentage parasitism, as well as activity, increases after a shower. This may be attributed to the increase in adult activity as well as to the softening of the stem, permitting easier insertion of the ovipositor. However, oviposition has been observed under hot, dry conditions in the fall of the year, when the wheat was almost ripe and the stems were dry and hard.

Because of the variability of weather conditions and because oviposition may last as long as an hour, it seems likely that no more than two to four eggs are laid daily by one female. The egg capacity of the female has not been determined, since adults do not develop a full complement of eggs at one time. Maturation is gradual, eggs becoming mature in batches, generally of six but sometimes of eight or ten.

Summary

Bracon cephi (Gahan) occurs in association with its host, *Cephus cinctus* Nort., in Western Canada but varies greatly in numbers from area to area. Limited laboratory and field rearing, dissection of larvae and adult females, and extensive field observations and surveys reveal the occurrence of two generations of adults. An external feeder, it hatches from an egg laid in the plant stem on or near the previously paralysed host larva, develops in about ten days, spins a cylindrical cocoon, and later emerges through a circular hole cut by the adult in the stem. The winter is passed as a mature larva in the cocoon. All stages are described.

Adult males live about three weeks and females about four. Eggs mature in about three weeks. Oviposition may last as long as an hour. The adults, which are positively phototactic, are most active during periods of sunshine following rain and at temperatures of 70° to 80°F.

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Determining Sample Size[1]

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The problem of sample size usually confronts the research worker in the initial stages of an investigation. Many short methods have been used for determining sample size such as extracting the square root of the number of boxes or taking a 10 percent sample. While these techniques are easy to use nevertheless they are not based upon a statistical evaluation of the experiment. Sample size in an experiment is often dictated by the amount of time, money and labor available but even under such conditions it is possible to evaluate the precision of the experiment when the number of replications is dictated by necessity.

To solve the problem of sample size three questions must first be answered;

1. What variation is expected in the experiment?
2. What differences between treatments would the experimenter like to estimate?
3. What accuracy of estimation is desired?

In order to obtain an estimate of experimental variation, previous results may be used as a guide if it is known that variation between years is not too great. If nothing is available from past data another method of approach is to conduct a dry run. This entails conducting a preliminary experiment and on the basis of that experiment an estimate of experimental error is obtained.

The second question asks for a statement of how closely the true difference between a pair of treatments is to be estimated. Specifically this can be done by stating the width of the confidence interval for the true difference. This is often expressed as percent of the mean.

The accuracy of the estimation rests largely with the observer. In most investigations today the 95 and 99 percent confidence probabilities are traditional. At these levels the errors of the first and second kind are minimized.

In fruit insect investigations, infestation of the treated plot is obtained by examining fruit from a tree and classifying it as defective or not. The percentage defective is then calculated. If the number of cherries to be selected from a tree receiving treatment is required, then the three questions must first be answered.

1. What experimental variation is expected in the population being sampled?

When dealing with percentage or binomial data this variation is given by the formula; $\sqrt{pq}$, where p equals the percentage expressed as a fraction defective and $q=1-p$. An approximate value of p can be used in the formula. If no estimate of p is available, $p=.50$ may be used since $\sqrt{pq}$ is greatest for this value of p.

2. How closely does the experimenter wish to estimate the true difference? Does he wish the precision of this sampling to be within 5 percent or 10 percent?
3. What confidence does the experimenter wish in the results?

Does he wish to state that if this experiment were performed 100 times 95 percent of the time the precision desired in question 2 above would be attained? If the level of infestation is known to be around $p=.40$ and the precision of the sampling is to be within 10 percent with a confidence level of 95 percent then the approximate sample size is given by;

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2Senior Biometrician.

$$n = \frac{2t^2pq}{D^2}$$
$$= \frac{8(.24)}{.01}$$
$$= 192$$

where t is the normal deviate corresponding to the level of significance in a two-tailed test. In this instance t equals 1.96 and D equals .10.

The above formula is approximate since the binomial only approaches the normal curve for large value of n. When p is close to .50 the approach to normality is even faster than when p is low. Furthermore the true value of the variance, pq, is not known but only estimated.

Whenever response data is collected in two-fold or four-fold tables other techniques are available. Statistical tables published by Mainland, (1948), can be used to estimate sample size.

Consider 45 apples from treated and control plots classified in a four-fold table as infested or non-infested apples as below:

	Treated	Control	Total
Infested	6	12	18
Not-infested	15	12	27
Total	21	24	45

A Chi-squared may be calculated to test the hypothesis that there is no relationship between infestation and the use of the insecticide. Chi-squared equals 1.34. Since this is less than the 5 percent level of significance, 3.84, the above hypothesis is not disproved. The infestation in the treated group was 28.6 percent and in the control group 50 percent. If this difference persisted when we examined more fruit a value would be obtained which would be significant. How large a sample would be required to make this difference significant?

In the tables used below it is assumed that equal numbers of control and treated samples can be obtained. Call the insecticide Sample 1 and the control group Sample 2. Since there is more infestation in Sample 2 (more A's in Mainland's terminology), the left hand side of Mainland's Table 6 is used with the minimum significant differences. Interpolation in Mainland's Table 6 yields 120 samples for each treatment making 240 samples in all. In other words, 240 samples would be required to establish a difference of 11.4 percent between the two groups as being significant at the 5 percent level.

When measurements are made on variables, Student's t test or the analysis of variance is used to obtain an estimate of experimental error. The accuracy of estimation is obtained from appropriate levels of significance from tables of Student's t. The example below will illustrate the procedure for estimating sample size.

The width of the postclypeus from 10 last instar specimens of larvae of *Choristoneura fumiferana* (Clem.) and 10 last instar specimens of larvae of *Choristoneura pinus* Freeman are given below as W_1 and W_2 respectively and are measured in eyepiece scale units.

W_1	W_2
4.7	4.8
4.9	5.4
5.0	4.6
4.6	5.0
4.9	4.7
4.7	5.2
5.1	4.7
5.0	4.8
4.5	5.3
4.6	5.5

Student's t test may be used to test if W_1 differs significantly from W_2 but in the table below the analysis of variance was used with the F test for testing significance.

ANALYSIS OF VARIANCE

Source of Variation	D.F.	M.S.	F
Between widths	1	.2000	2.69
Error	18	.0744	
	19		

Since the calculated F=2.69 is less than $F_{.05}$=4.41, the average widths of 4.80 units and 5.00 units do not differ significantly at the 5 percent level of significance.

What sample size would be needed to establish that the difference of .20 units is significant at the 1 percent level? An estimate of experimental variation, .0744, with 18 degrees of freedom is obtained from the analysis of variance. From Student's table the t value for 18 degrees of freedom at the 1 percent level of significance is 2.88. Substitution of these values in the formula for sample size given below yields:

$$n = \frac{2\ t^2\ V}{D^2}$$

$$= \frac{2(2.88)^2(.0744)}{.04} = 30.84$$

A sample size of 31 larvae from each of the two groups would be sufficient to establish that the above differences would be significantly different from zero at the 10 percent level.

The difference, D, and the square root of the variation in the above formula may be expressed as a percentage of the overall mean:

$$D = \frac{.20}{4.90} = 4.08\%$$

$$C.V. = \frac{\sqrt{.0744}}{4.90} = \frac{.27}{4.90} = 5.51\%$$

where C.V. is the coefficient of variation. The formula for sample size may be re-written as follows:

$$n = \frac{2\ t^2\ (C.V.)^2}{D^2}\ ,$$

When estimates of the variance of factors which may contribute to the total variance are required, their variance components may be obtained from an analysis of variance and their separate contributions to the total variance examined.

In the sample of insect infestation on apple trees it is essential to know the number of leaves per tree, the number of trees per plot and the number of replicates to be used. Data from a dry run conducted in 1951 at Kentville, N.S., are used below to illustrate the technique of determining sample size by variance components. In this experiment 20 leaves per tree and 5 trees per plot were randomly selected. The experiment was arranged in two randomized blocks of 4 treatments each. Records of eggs of red mites were sampled on 5 dates. The records were collected so that leaf to leaf variation could be analyzed.

Before the egg counts per leaf were analyzed it was noted that the standard deviation for each of the treatments was positively correlated with the treatment means, (Snedecor, 1940). This is usual in entomological data and before an analysis can be made of the data a transformation should be used to remove

this relationship. The presence of correlation between standard deviation and means is an indication that the counts are not normally distributed. An appropriate transformation of the counts would make the transformed counts approximately normally distributed so that significant tests could then be made from the analysis of variance.

The appropriate transformation may also make the difference from one replicate to another the same for all treatments. This property is called additivity and is to be desired in an analysis.

The transformation applied to the counts of red mite eggs was the logarithm of 1 plus the number of mites found on each leaf. The L_1 tests for the transformed and the untransformed egg data are shown below in Table I.

TABLE I

L_1 values for egg counts, (x), and transformed egg counts, log(1+x), by dates.

Date	x	log(1+x)
a	.4898	.6527
b	.2834	.8493
c	.1682	.8438
d	.2140	.8709
e	.1375	.8050
all dates	.2446	.8303

It will be noticed that the transformation increased the L_1 values. The maximum value of L_1 is I when all variances are equal. In no cases did the L_1's approach significance. Other transformations were investigated but the logarithmic transformation was the one which increased the L_1 values the most. It was felt that the logarithmic transformation should be used even though it did not completely remove the relationship between the mean and the standard deviation.

The analysis of variance for red mite egg counts is given below in Table II with the variance components.

TABLE II

Source of Variation	D.F.	M.S.	F.	Mean square is an estimate of
Replicates	1	21.3759	n.s.	
Treatments	3	75.3436	n.s.	
Dates	4	95.3311	16.49**	
T x D	12	14.2053	n.s.	
R x T	3	40.3540	6.98**	$\sigma_1^2+20\sigma_t^2+100\sigma_{RDT}^2+500\sigma_{RT}^2$
R x D	4	11.7936	n.s.	
R x D x T	12	5.7820	10.25**	$\sigma_1^2+20\sigma_t^2+100\sigma_{RDT}^2$
Trees	160	.5638	4.29**	$\sigma_1^2+20\sigma_t^2$
Leaves	3800	.1313		σ_1^2
Total	3999			

The appropriate error term for testing between tree variation is between leaf variation. To test if the three factor interaction, R x D x T, is significant, the between tree variation is used. Since the three factor interaction is significant, it is used to test each of the two factor interactions. It will be noticed that neither the T x D nor the R x D interactions are significant, hence the two variance components associated with these two interactions do not exist. Since the R x T interaction is highly significant it is used to test if treatments differ.

The standard error for the difference between two treatment means may then be written:

$$\sigma_d = \sqrt{2}\ \frac{\sigma_{RT}}{\sqrt{drtl}}$$

or

$$\sigma_d = \sqrt{2}\ \sqrt{\frac{\sigma_l^2}{drtl} + \frac{\sigma_t^2}{drt} + \frac{\sigma_{RDT}^2}{dr} + \frac{\sigma_{RT}^2}{r}}$$

where r is the number of replicates
t is the number of trees per plot
l is the number of leaves per tree
d is the number of dates on which the records were made.

In solving for the variance components we have:

$$\sigma_l^2 = .1313$$
$$20\sigma_t^2 = .4325$$
$$100\sigma_{RDT}^2 = 5.2182$$
$$500\sigma_{RT}^2 = 34.5720$$

This is a breakdown of the R x T interaction variance, 40.3540. The leaf to leaf component contributes 0.33 percent to the total variation, the tree to tree component contributes 1.07 percent, the three factor interaction component, 12.93 percent and the two factor interaction component contributes 85.67 percent. Since the two factor interaction component contributes so much to the total variation and since its denominator in the standard error of the difference of two treatments is r, the number of replicates, the standard error of the experiment can best be reduced by increasing the number of replicates.

An examination of Table III used for computing the R x T interactions will show why more replicates are needed.

TABLE III

Totals for transformed egg counts for all dates, all trees, all leaves

		Treatment			
		1	2	3	4
Replicates	1	465.35	494.59	100.20	111.04
	2	198.48	303.76	80.03	296.50

Replicate 1 is higher in transformed numbers of insects for treatments 1, 2 and 3 but lower on treatment 4. This is the reason why the R x T interaction mean square is high and why its component is large.

On substituting the variance component values obtained from the analysis of variance table in the numerator of the standard error we have:

$$\sigma_d = \sqrt{2}\ \sqrt{\frac{.1313}{drtl} + \frac{.0216}{drt} + \frac{.0522}{dr} + \frac{.0691}{r}}$$

For two replicates and five dates various numbers of trees per plot and leaves per tree were substituted in the above standard error to determine how the standard error may best be reduced. The results are shown below in Table IV.

TABLE IV

Standard error of the difference of two means for 2 replicates and 5 trees

	Trees per Plot				
	2	3	4	5	6
Leaves 5	.2052	.2032	.2022	.2017	.2012
per 10	.2037	.2022	.2015	.2010	.2007
Tree 15	.2039	.2017	.2012	.2007	.2005
20	.2029	.2017	.2010	.2007	.2005
25	.2027	.2015	.2010	.2005	.2005

No great increase in the experiment can be expected by increasing the numbers of leaves per tree and trees per plot. Since the tree variance component is larger than the leaf variance component the precision is improved more by increasing the number of trees than by increasing the number of leaves. In fact, 4 trees of 10 leaves each gives the same precision as 3 trees of 25 leaves each.

If 3 replicates are used each of the above standard errors are multiplied by $\sqrt{\frac{3}{2}}=.8165$ and a reduction of 18 percent then obtained. Thus an increase in the number of replicates would result in greater precision in detecting differences between treatments than would increasing the number of leaves per tree or trees per plot.

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The Types of Hydradephaga in the W. S. Blatchley Collection, with Generic Reassignments and Synonymies (Coleoptera: Noteridae, Dytiscidae, Gyrinidae, Haliplidae)[1]

By FRANK N. YOUNG

The W. S. Blatchley collection of Coleoptera, now at Purdue University, Lafayette, Indiana, contains thirteen primary types of Hydradephaga described by Blatchley. Some of the species represented have not been recognized by subsequent workers, while others have been synonymized without the original types having been seen. The following notes and comments therefore seem pertinent, and may prove of value to others engaged in the study of this group of insects.

Blatchley did not originally designate specific specimens as types, but since his original descriptions include dates and localities the type specimens are not usually hard to fix. Further, he published (1930) a list of all species described by him together with fixation of types of genera and type specimens. Wherever specimens so indicated are in agreement with the original description and locality data they have been accepted as equivalent to holotypes in the current sense. Cotypes or syntypes are not indicated in any of the species considered here. Many of Blatchley's series were composite and consideration of syntypes might lead to much confusion. Specimens fixed as types in the 1930 list are marked with red labels reading "TYPE."

[1]Contribution No. 496 from the Department of Zoology, Indiana University, aided by a grant from the National Science Foundation.

I want to thank Dr. J. J. Davis of Purdue University and his staff for allowing me to examine the Blatchley collection and for other assistance.

Family Noteridae

Pronoterus addendus (Blatchley) new combination

1920 *Canthydrus addendus* Blatchley, *Can. Ent.*, 52: 261 Type Male: Dunedin, Pinellas County, Florida. April 1, 1920 W. S. Blatchley.

The type specimen agrees well with specimens from Dade, Highlands, Pinellas, and Volusia counties, Florida except in being somewhat larger than average. Length of type about 2.94 mm.; greatest width near middle of elytra 1.43 mm. Average length of other specimens examined about 2.8 mm.

The rounded apex of the prosternal process, weakly developed protibial spurs, and the enlarged intermediate segments (6–9) of the male antennae place the species in *Pronoterus* Sharp (Genotype: *Pronoterus punctipennis* Sharp, 1882). The side margins of the pronotum are entire as in *Hydrocanthus* and *Canthydrus*, not incomplete as in *Suphisellus*.

Blatchley (1932) apparently recognized the generic distinction of *semipunctatus* (LeConte), placing it in *Pronoterus*, but did not mention his own species. *Addendus* can be distinguished from *semipunctatus* by its larger size, more convex body form above, and darker color of the elytra which varies from dark reddish brown to piceous. The punctation of the elytra is very coarse in *semipunctatus* and tends to form several irregular striae; in *addendus* the elytral punctation is finer, denser, and the striae more numerous and irregular. Several specimens of *semipunctatus* from Dade, Citrus, and Highlands counties, Florida average about 2.4 mm. in length.

Suphisellus floridanus (Blatchley)

1914 *Canthydrus floridanus* Blatchley, *Can. Ent.*, 46: 63 Type Male: Lake Okeechobee, Florida. March 6, 1913 W. S. Blatchley.

The type compares exactly with numerous specimens from Dade County, Florida and other parts of the state. I believe that the type is a male although Blatchley (1930) says that it is a female. The species is separable from *gibbulus* (Aubé) by its shorter and more convex form, finer dorsal punctation, darker elytra, and the narrower prosternal process between the anterior coxae. Some small forms of *gibbulus* which possess a dark blotch on the middle of the front margin of the pronotum may be confused with *floridanus*, but can be separated by close attention to the difference mentioned above. Once *floridanus* is seen it is hard to mistake it for any other North American species. Length of type about 2.10 mm.; greatest width near base of elytra 1.27 mm.

Dr. P. J. Darlington, Jr. does not believe that *floridanus* is specifically distinct from *Suphisellus insularis* (Sharp) described from San Domingo. This point can be settled, I believe, only by comparison of specimens with Sharp's type.

Family Dytiscidae

Hydrovatus indianensis (Blatchley)

1910 *Hydrovatus indianensis* Blatchley, Coleoptera of Indiana, p. 212. Type Female: Kosciusko County, Indiana. Aug. 5, 1904 W. S. Blatchley.

The female type of this species is certainly distinct from *pustulatus* (Melsheimer), but without males for comparison its exact placement must remain uncertain.

Partial Redescription: Head very finely, almost imperceptibly punctate; microreticulate; the clypeus distinctly margined. Pronotum very coarsely punctate, the punctation in part giving way to vermiculate sculpture; punctures finer toward the sides; strongly microreticulate, the meshes rather deeply impressed.

Elytra very coarsely punctate, much like the disk of the pronotum; punctures finer toward the sides; microreticulation similar to that of pronotum, but not as deeply impressed; sides of elytra without a submarginal groove or sulcus. Coxal plates somewhat more coarsely and densely punctate than elytra; the punctures not confluent. First and second apparent abdominal sternites with vermiculate sculptures, the others microreticulate but without conspicuous punctures. Last ventral with a small blunt process, somewhat flattened at middle and smooth. Length about 3.05 mm.; greatest width at basal one third of elytra 1.94 mm.; length of pronotum at midline 0.68 mm.; width pronotum at base 1.73 mm.; width pronotum at apex 1.16 mm.; length of elytra at suture 2.12 mm.

The color pattern is essentially as described by Blatchley, but the color does not appear darker than in many specimens of *pustulatus* I have seen.

A second specimen, apparently placed with the type by Blatchley, has been lost.

***Pachydrus princeps* (Blatchley)**

1914 *Coelambus princeps* Blatchley, *Can. Ent.*, 46: 65 Type Male (?): Lake Okeechobee, Florida. Mar. 6, 1913 W. S. Blatchley.

The type compares well with numerous specimens taken throughout Florida and in southern Georgia. Blatchley (1932) records the first specimen of *princeps* as from Brentley's Fish Camp on Pelican Point (near present site of Pahokee), Mar. 7, 1913. Later (1938) he erroneously cites type as being from Dunedin, Florida. This species is very close to *Pachydrus obniger* Chevrolat from Cuba, but there seem to be small but consistent difference in color pattern and punctation in the specimens I have examined.

***Hygrotus marginipennis* (Blatchley)**

1912 *Coelambus marginipennis* Blatchley, *Can. Ent.*, 44: 330 Type Female: Sarasota, Sarasota County, Florida. Mar. 2, 1911 W. S. Blatchley.

Blatchley (1930) designates as type a male from Sarasota, Florida taken Mar. 2, 1911. There are now no males in his collection from Sarasota although there are two females mounted on the same point dated Mar. 2, and bearing the red type label. Another female from Sarasota is dated Mar. 1, 1911. Five males are from Dunedin, Florida (Jan. 1, 1918, Mar. 18, 1919); LaBelle, Florida (Feb. 26, 1918); and Hl (Hillsborough) Canal, Florida (Mar. 24, 1922). There are also two females from Dunedin (Mar. 16, 1913). In the absence of a male from Sarasota in his collection, I believe that we must consider the outer female on the point bearing the date Mar. 2, 1911 as the type. Length about 2.39 mm.; greatest width near middle of elytra 1.57 mm. The largest female I have seen (Alachua County, Florida) measures 2.57 mm. in length; the smallest male 2.21 mm.

Judging from the specimens I have seen *marginipennis* is rather variable. The color pattern in all, however, is diffuse and rather distinct from that of *acaroides* (Le Conte), and the small carinae on the sides of the elytra are usually reduced and indistinct. The male sexual structures are similar to those of *acaroides, i.e.* there is an excavation in the last ventral sternite from the anterior margin of which two slender setae (?) project backward, and from the side margins toward the back a short spine curves inward on either side accompanied by several hair-like setae. Lacking evidence of intergradation with *acaroides*, I believe that we would consider *marginipennis* as a distinct species. H. C. Fall (1919) consider it merely a variety of *acaroides*, but if it does intergrade with the typical *acaroides* I believe it will prove to be a distinct (allopatric) subspecies.

***Desmopachria mutchleri* (Blatchley)**

1919 *Desmopachria mutchleri* Blatchley, *Bull, Amer. Mus. Nat. Hist.*, 41 (4): 309 Type Male: Dunedin, Pinellas County, Florida. Mar. 22, 1919 W. S. Blatchley.

The type compares well with numerous specimens that I have seen from Alachus, Broward, Dade, Hernando, Levy, and Pinellas counties, Florida, except in being somewhat smaller than average.

***Bidessonotus longovalis* (Blatchley)**

1919 *Bidessus longovalis* Blatchley, *Bull. Amer. Mus. Nat. Hist.*, 41 (4): 310. Type Male: Kissimee, Osceola County, Florida. Feb. 16, 1913. Marked "Kiss. Riv." W. S. Blatchley.

The type is a male *Bidessonotus* which agrees with specimens which I have dissected and the genitalia of which agree with the figure given by Balfour-Browne (1947). See Balfour-Browne (1947: 431) for a redescription of this species. It is interesting in that it apparently does not occur in the extreme southern part of Florida, but seems to be restricted to the northern and central counties. I have seen specimens, checked by examination of male genitalia, from Alachua, Hendry, Levy, Madison, Pinellas, Polk, Putnam, and Taylor counties.

***Bidessonotus pulicarius* (Aubé)**

1838 *Hydroporus pulicarius* Aubé, Species Général des Coléopt., 6; 494. Described from the United States.

1919 *Bidessus subsericeus* Blatchley, *Bull. Amer. Mus. Nat. Hist.*, 41 (4): 311. Type Female: Dunedin, Pinellas County, Florida. Jan. 25, 1918, W. S. Blatchley.

The type female compares exactly with numerous females seen from various localities in Florida. The small ante-apical epipleural teeth on the elytra are conspicuous. See Balfour-Browne (1947: 433-434) for a redescription and figures of the male genitalia.

***Hydroporus (Sternoporus) uniformis* Blatchley**

1925 *Hydroporus uniformis* Blatchley, *Can. Ent.*, 57: 162 Type Male: Royal Palm State Park, Dade County, Florida. Mar. 14, 1924 W. S. Blatchley.

The type agrees exactly with topotypic specimens from Royal Palm State Park and with several specimens from Miami, Florida. A single female from Broward County, Florida, however, shows indications of a fasciate color pattern similar to that seen in other members of the *undulatus* complex. The species is probably most closely allied to *lobatus* Sharp, but shows some affinities with *hebes* Fall. The claws of the anterior tarsi of the male are not greatly modified, but the tarsal segments are expanded. The type measures about 4.1 mm. in length. The general size of all specimens seen average somewhat less than Floridian specimens of *lobatus*.

***Hydroporus (s. str.) falli* Blatchley**

1925 *Hydroporus falli* Blatchley, *Can. Ent.*, 57: 162 Type Female: Dunedin, Pinellas County, Florida. Apr. 2, 1923 W. S. Blatchley.

The type female of this species compares almost exactly with numerous females taken in other localities in northern Florida. The coarse dorsal punctation, broad rather thick body form, and the broad prosternal process should allow determination even in the absence of males.

Blatchley described this species as being in the *pulcher-undulatus* group of Fall (= *Sternoporus*), but it is apparently a *Hydroporus* (*s. str.*) similar to *niger* and *rufilabris*. (Specimens in my collection were determined as *niger* by Fall in 1938). The characters by which the species can be grouped with *undulatus* are rather feeble. The sulcuation on the metasternum stressed by Blatchley is not very evident in the type, but somewhat more so in other specimens I have seen. The condition is about intermediate between that in

undulatus and in *niger*. The angulation of the hind coxal processes, although evident, is not different from that seen in some undoubted members of *Hydroporus* (*s. str.*). The lateral margins of the pronotum are narrow and not widened anteriorly, although somewhat wider in the females than in the males.

A male, which compares well with Blatchley's type, was examined by Mr. H. B. Leech, who writes that it is a very distinctive species.

Males of *falli* are separable from either *niger* or *rufilabris* by the much coarser and sparser dorsal punctation, by the broader prosternal process, by the angulation of the hind coxal processes, and by the much coarser punctation of the metacoxal plates and first and second abdominal sternites. The middle of the abdominal sternites after the second is very finely punctate as described by Blatchley. The male genitalia are somewhat similar to those of *niger*, but the aedeagus is broader toward the tip and the tip is reflexed, giving the end a rather blunt appearance. The broadly rounded tip of the aedeagus of *rufilabris* should readily distinguish that species. The anterior claw of the protarsus of the male of *falli* is perceptibly shorter than the posterior claw, rather sharply curved at the base, and feebly sinuate on the inner edge. It differs from the anterior protarsal claw in *rufilabris* in the sharper curve at the base and in the lack of the dilatation on the inner edge. It differs from that of *niger* in being slenderer, not enlarged at the base, not incrassate, and only feebly sinuate to the tip. The posterior claw of the protarsus in *falli* is slender, rather long, and not at all sinuate. It appears to be proportionately longer than in either *rufilabris* or *niger*.

Length of type female, 4.40 mm.; greatest width 2.35 mm. Length of another female in Blatchley collection with same data as type, 4.53 mm.; greatest width 2.54 mm. Several males measured range in length from 4.40 mm. to 4.61 mm. greatest width 2.36 to 2.54.

***Agabus confusus* (Blatchley) new combination**

1910 *Rhantus confusus* Blatchley, Coleoptera of Indiana, p. 229, fig. 113. Type Male: Floyd County, Indiana. Sept. 28, 1901 W. S. Blatchley.
1922 *Agabus amplus* Fall, Review of North American Species of *Agabus*, p. 10, 12. Type Male: Missouri (Oberthür Collection), bearing label "*brevicollis* Lee." in Oberthür handwriting, in J. D. Sherman Collection now at the U. S. National Museum. (New synonmy).

The type of *confusus* agrees in all essential features with Fall's description of *amplus* and with a number of specimens from various parts of Indiana. The hind tarsal claws have been broken off the type, but in all other specimens seen they are approximately equal. The other characters are those of *Agabus*, and superficially, at least, place the species with *stagninus* and *semivittatus*. Blatchley apparently recognized the generic position of *confusus* since his specimens are labeled "*Agabus confusus* Blatchley," but he apparently made no published admission. Although I have not seen the type of *amplus* Fall, I believe that the synonmy given above will stand.

The figure given by Blatchley (1910, fig. 113) is a fair but not exact representation of the type. The specimen is somewhat more compacted anteriorly than shown and the elytral striae of punctures are not so distinct. The unequal hind tarsal claws were probably added to complete the figure, since the legs are not in the position shown.

Besides the type I have seen the following specimens: Indiana, Brown County, W. S. Blatchley (5); Indiana, Monroe County, various collectors (17). Montgomery and Amos (1941) list a specimen determined as *Rhantus confusus* from Clark County State Forest, Indiana. *Amplus* was described from the type

male from Missouri as indicated, and a female labeled "Kentucky, Sanborn." Further records to establish the exact range of this interesting species would be very desirable.

Family Gyrinidae

Gyrinus piceolus Blatchley

1910 *Gyrinus piceolus* Blatchley, Coleoptera of Indiana, p. 240. Type Male: Lake County, Indiana. May 5, 1907 (given as 1905 in Blatchley's 1930 paper). W. S. Blatchley.

The type male bears a note apparently in Blatchley's handwriting: "Resembles both *affinis* and *aenolus*. Had with the latter, but undersurface black." The species resembles *pernitidus* LeC. with which it was synonymized by Fall (1922), but is readily distinguishable by the male genitalia. J. B. Wallis (1926) discusses the status of *piceolus*. Length of type, from tip of elytra to front margin of head, 4.5 mm.

The genitalia of the type (now extracted and mounted with specimen) resemble in outline those of *marginellus* Fall as figured by him (1922, pl. xvi, fig. 7), but differ in the more constricted middle of the aedeagus and in the wider, more rounded and somewhat concave tip. The tip of the aedeagus somewhat resembles a small measuring spoon or spatula.

Other male specimens with identical genitalia in the Blatchley collection are from Lafayette, Indiana, Mar. 31, 1925, B. E. Montgomery; and Pittsfield Township, Washtenaw County, Michigan, May 28, 1919, M. H. Hatch. The Lafayette specimen measures 4.8 mm. from the tip of elytra to front margin of head. This specimen bears two labels: one reading "piceolus Blatchley", the other, possible in Fall's handwriting indicating that it represents a very distinct species of which a long series would be desirable. Dr. Montgomery believes that the specimen may have been sent to Fall for determination.

Family Haliplidae

Peltodytes pedunculatus (Blatchley)

1910 *Cnemidotus pedunculatus* Blatchley, Coleoptera of Indiana, p. 204. Type Male: Laporte County, Indiana. July 21, 1907 W. S. Blatchley.

The type agrees essentially with the characterization given by Roberts (1913: 120). The species seems to be distinct from *muticus* or *sexmaculata*, but its relationship to these and other species needs consideration.

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A New *Zygethopolys* from Kentucky and a Key to the Members of the Genus. (Chilopoda: Lithobiomorpha: Lithobiidae: Ethopolyinae)

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Almost all of the members of the subfamily Ethopolyinae[1] occur in western North America, a few Pacific islands, the Orient and Europe, but only one established[2] species had been known from North America east of the Rocky Mountains. This widespread and very common form, *Bothropolys multidentatus* (Newport), ranges throughout the East as far west as Missouri. The present new species is therefore of special interest in that it is the second endemic member of the subfamily to be recorded from east of the Rockies. The only other members of *Zygethopolys*, a genus closely allied to *Bothropolys*, are known only from Alaska, British Columbia, and the state of Washington.

The new species differs from both west coast forms in that its sixth and seventh tergites are strongly produced. In addition, its ultimate pretarsus possesses an outer accessory claw, whereas that of the genotype, *nothus* Chamberlin, does not, and the ultimate tibia of *atrox* is conspicuously swollen dorsodistally, but that of *pugetensis* Chamberlin is unmodified.

Zygethopolys atrox sp. n.

Type. ♂; Cumberland Falls State Park, Whitley county, Kentucky, April 14, 1952. (Theodore J. Spilman; under a rock). In author's collection, C-1446.

Total length: 32 mm. *Color*: head and last three pedal tergites bright orange, intervening tergites orange medially, whitish peripherally; last two pairs of legs bright orange, remaining legs whitish. *Antennae*: left with nineteen articles; right with ten articles, broken. *Cephalic plate*: about as long as wide, posterior corners square, anteriorly strongly angular; width of head to that of first pedal tergite 33:36; lateral margins unbroken; ocelli 1-6, 7, 5, 6, 6, 5. *Prehensorial segment*: prosternal teeth 9-8; medial diastema very narrow and deep, rounded basally; porodont[3] on each side separating the outermost tooth from the others. *Tergites*: 6, 7, 9, 11, and 13 strongly produced; 16th tergite projecting by a third of its length beyond the genito-anal segments. *Sternites*: one through the sixth sparsely setose; seventh through the fourteenth increasingly densely setose, the thirteenth and fourteenth each densely clothed with short, stiff setae, each of

1The family Lithobiidae is considered here to be divisible into two subfamilies, Lithobiinae and Ethopolyinae, the latter of which is equal to Ethopolidae Chamberlin, and to Attems' tribe Polybothrini.
2Known only from New Orleans, Louisiana where it was intercepted at quarantine. *Bothropolys epelus* Chamberlin (Pan. Pac. Ent., VII, p. 190, 1931) is not believed to have established itself in this country.
3Porodont—a term coined by Verhoeff to describe the stout seta that flanks the prosternal teeth.

these two sternites with a number of non-setose excavations of various configurations the most prominent of which is a medial trident figure with anteriorly directed arms; fifteenth sternite sparsely setose and without excavations. *Legs*: one through thirteen each with two large pretarsal accessory claws, the fourteenth and fifteenth pretarsi each with only an outer accessory claw; all tarsi completely bipartite, each tarsal division surmounted dorsally with a distinct condyle. *Ultimate legs of male*: femur with a shallow longitudinal dorsal fossa extending two-thirds the article's length proximad, at distal end of fossa there is a small group of short, clavate setae; tibia distally surmounted dorso-mesally with a prominent swelling covered with numerous short, clavate setae. *Male gonopods*: each consisting of a single short article. *Plectrotaxy*:[4]

		Dorsal					Ventral			
Leg	Coxa	Pref.	Fem.	Tib.	Leg	Coxa	Troch.	Pref.	Fem.	Tib.
1.		amp	ap	a	1.			mp	amp	am
2.		amp	ap	ap	2.			mp	amp	am
3.		amp	ap	ap	3.			mp	amp	am
4.		amp	ap	ap	4.			mp	amp	am
5.		amp	ap	ap	5.			mp	amp	am
6.		amp	ap	ap	6.			mp	amp	am
7.		amp	ap	ap	7.			mp	amp	am
8.	a	amp	ap	ap	8.			mp	amp	am
9.	a	amp	ap	ap	9.			amp	amp	am
10.	a	amp	ap	ap	10.			amp	amp	am
11.	a	amp	ap	ap	11.			amp	amp	am
12.	a	amp	p	p	12.		m	amp	amp	am
13.	a	amp	p	p	13.		m	amp	amp	am
14.	a	amp	p	p	14.	m	m	amp	amp	a
15.	a	amp	p		15.	m	m	amp	amp	a

Key to the Species of *Zygethopolys*

1. Tergites 6, 7, 9, 11, and 13 strongly produced (Kentucky) ..... *atrox* sp. n.
   Tergites 9, 11, and 13 strongly produced, others straight 2
2. Last pair of coxae laterally armed. Ventral armature of ultimate legs 1, 1, 3, 3, 1 (Alaska) ..... *nothus* Chamberlin
   Last two pairs of coxae laterally armed. Ventral armature of ultimate legs 1, 1, 3, 2, 1 ..... *pugetensis* Chamberlin 3
3. Basal spurs of female gonopods 2-2, inner denticle of claw almost as long as medial denticle (Washington) ..... *pugetensis pugetensis* Chamberlin
   Basal spurs of female gonopods 3-3, inner denticle of claw much shorter than medial denticle (British Columbia) ..... *pugetensis tiganus* Chamberlin and Wang

[4]Plectrotaxy (Πλῆκτρον —calcar—spur), the arrangement and nomenclature of the pedal spurs of Lithobiid centipedes. The system employed here is discussed in Faune de France, XXV, (1930).

The Runge Press Limited, Ottawa
Mailed: Wednesday, April 15, 1953